WONDERS OF THE HUMAN BODY.

THE HUMAN BODY.

WONDERS
OF THE
HUMAN BODY:

A POPULAR ACCOUNT
OF THE
VARIOUS MEMBERS OF THE HUMAN FRAME,
THEIR CONSTITUTION, AND THE FUNCTIONS THEY DISCHARGE.

FROM THE FRENCH
OF

A. LE PILEUR,
DOCTOR OF MEDICINE.

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PUBLISHERS' PREFACE.

THERE is an increasing tendency in the present day to make common property of special knowledge. Even such information as formerly belonged to certain professions alone is, at least in its rudiments, becoming more generally diffused; and on the part even of those professions the tendency is recognized as within reasonable bounds deserving of encouragement.

To take "the human body" as an illustration, medical men find that the useful feature of their art is facilitated by the dissemination of information regarding its structure and functions. On the other hand, the public daily see more and more clearly that "prevention is better than cure," and that to prevent derangements of the wonderful machine, with the guidance of which each individual is intrusted, more acquaintance with its mechanism and laws of normal action is indispensable. Apart from its utility, a knowledge of anatomy and physiology is gradually becoming a necessary part of a liberal education.

To meet these requirements the Publishers now present this translation from the French of a book which, in the original, has attained to great popularity. While sufficiently

minute in anatomical and physiological details to satisfy those who desire to go deeper into such studies than many may deem necessary, this work is nevertheless written so that it may form part of the domestic library. Mothers and daughters may read it without being repelled or shocked; and the young will find their interest sustained by incidental digressions to more attractive matters. Such are the pages referring to phrenology and to music, which accompany the anatomical description of the skull and of the organs of voice; and the chapter on artistic expression which closes the book.

Attention may also be directed to the numerous accurate and also simple engravings, which have been introduced in the hope of elucidating the verbal descriptions in the text.

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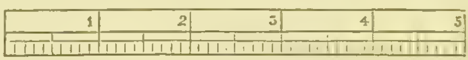
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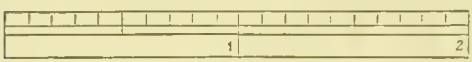
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FRENCH AND ENGLISH MEASURES OF LENGTH.

HALF A DECIMETRE DIVIDED INTO CENTIMETRES AND MILLIMETRES.



INCHES AND TENTHS.



1 Millimetre	= .03937079 inch, or about $\frac{1}{25}$ inch.
1 Centimetre	= .3937079 inch.
1 Decimetre	= 3.937079 inches.
1 Metre	= 39.37079 inches, or 3.2809 feet nearly.
1 Inch	= 25.39954 millimetres.
1 Foot	= .30479449 metre.
1 Yard	= .91438347 metre.

For the sake of precision, the smaller French measurements have been allowed to stand in the following translation without conversion into their English equivalents. The table above will enable the reader easily to find their values in English measure.

THE

HUMAN BODY.

CHAPTER I.

INTRODUCTION.

Opinions of the ancients concerning the human body.—Summary of general anatomy.—Substance of the body or organized matter.—Anatomical elements.—Nutrition.—Fluids.—Tissues.

It has been said with truth, that the human mind, which can survey the heavens and calculate the motion and density of the stars, finds itself confounded when, returning from these distant journeyings, it enters its own proper dwelling-place. Man's own organization is still among those mysteries of nature which he is least able to penetrate, in spite of his incessant efforts to lift the veil which hides it. In all ages he has sought to *know himself;* in all times he has studied the relations between his own existence and that of the world; and those universal influences which, though evident to him, are nearly all inexplicable in their action upon living beings.

Carried by their imagination into this way of comparing the human body with the rest of creation, Aristotle and some other philosophers saw in man an epitome of the wonders of the universe. He was for them the microcosm, the diminutive and summary of the entire world.

Paracelsus and the astrological doctors developed from their stand point the ideas of the Greek philosophers, and pushed to its extreme limits the doctrine of sidereal influence

upon man. According to them, the body had, like the earth, an axis and two poles; the head, the seat of the soul, corresponded to the heavens where divinity resided, &c.

Since that time, and especially in our own day, the imagination has given way to a rigorous method of study and to positive ideas. But whether we venturously follow Aristotle and Paracelsus, or whether we prefer the exact results of science to their poetic theories, we shall always see in the human body the highest and most perfect creation of nature among living beings, and we shall admire the efforts and the discoveries which the study of its organization has enabled the mind to make from the time of the masters of antiquity down to our own day.

In the human body, as in animals and in the vegetable kingdom, the organized matter is composed of what are termed *proximate* (or immediate) *principles* and *anatomical elements.* Of these proximate principles some are of mineral origin, as oxygen, water, the carbonates, the chlorides, the phosphates, &c. They penetrate the organism, and there furnish the materials, by the aid of which other principles of a different order are formed. These last essentially constitute the body, hence the name *organic substances* is specially applied to them. There is nothing in the mineral kingdom analogous to these organic substances, though they borrow their original elements from it. They are solid or semi-solid (globuline, musculine), liquid or semi-liquid (fibrine, albumen, caseine), colouring or coloured (hematosine, biliverdine). They decompose where they are formed, and give birth to another class of proximate principles. These last are of very different natures, and possess different attributes: they are acids, salts, alkaloids, fatty bodies: they are urea, creatine, stearine, cholesterine, and the sugar of the milk and of the liver, lactic acid, uric acid, &c.

This double and continuous movement of combination and resolution of proximate principles results in the formation of the *anatomical elements.* This is the term applied to very minute bodies, free or attached, which present special geometrical, physical, and chemical characters, as well as a structure which has no analogy to that of minerals.—They

are the smallest organic subdivisions of which the tissues and fluids are capable by anatomical analysis. Their reunion and combination form the solids and liquids of the organism. By *assimilation* they borrow their substance from the molecules of the proximate principles, while at the same time and in equal proportions they abandon other molecules of these same principles by a process of separation.

This assemblage of phenomena is termed *nutrition*. In this manner water, carbon, lime, phosphorus, iron, and the other principles, co-operate in forming globuline, fibrine, musculine, and the other organic substances, which by their combination constitute the anatomical elements of the blood, the muscles, the bones, the nerves, the *body* in a word; this is assimilation.

At the same time other molecules of the same principles, in equal proportions, abandon by a separatory process the substance of the organism, and unite to form the milk, saliva, tears, bile, and the other secretions, which are to be completely excreted as improper for nutrition, or partially thrown off and partially returned to the system.

As to the anatomical elements, some of them have a form which may be described, as globule, fibre, tube, and cell; others are amorphous, and serve to fill the spaces between those first-named.

We see therefore that the immediate or proximate principles and the anatomical elements constitute all organized matter whether solid or fluid.

The fluid portions of the human body greatly exceed the solid; they are computed at nine-tenths of the whole weight. Water enters largely into the composition of these fluids, a portion of which only is contained in the vessels or reservoirs specially set apart for each of them, while the remainder penetrates the solid parts and forms part of their substance.

The term *humours*—fluids—is applied to the liquid or semi-liquid portions of the organism formed by the mingling and dissolution of immediate principles, and they ordinarily hold the anatomical elements in suspension. The solid portions are called *tissues*.

These fluids are classed, according to the part they play in the human economy, into constituent fluids, secreted fluids, or secretions, excretions, and intermediate products, which partake of the nature of the other three. The constituent fluids are three in number—the blood, chyle, and lymph. The blood is the nutritive fluid of the body; it contains all the immediate principles that are found in its organism. Incessantly renewed by digestion and respiration, it supplies to each organ assimilable matter, and to the special laboratories the materials for the secretions, and carries off the results of disassimilation which are to be thrown out of the organism. It is therefore at once a reparative and a purifying fluid. The term "fluid flesh," which has been applied



Fig. 1.—Blood seen under the microscope.

to it, is incomplete, for it contains not only the muscular tissue, but the essential elements of all the other tissues are found in its mass.

The blood is heavier than water, its specific gravity being 1052 to 1057, while that of water is 1000. In the blood-vessels the blood is composed of—1st. anatomical elements, *red* and *white corpuscles*. 2d. Of a fluid, of which 770 parts in weight in 1000 are water in men, and in women 791 parts in 1000. This fluid is the *plasma*, the plastic substance, the nourishing juice in which are found all the immediate

principles of the blood. Among these principles are lime, ammonia, soda, potash, phosphorus, magnesia, iron and other metals in the form of salts; chlorides, sulphates, carbonates, phosphates, &c.; and mingled with these are the principles of the secretions and organic substances, of which the most important, from their quantity, are—fibrine, 2·5 parts in 1000, and albumen 69 to 70 in 1000.

The blood owes its colour to the *red corpuscles*, which are themselves coloured by a substance which De Blainville has named *hematosine*, and which contains 7 parts in 100 of iron. These corpuscles are round flattened disks of ·006 to ·007 of a millimètre in diameter, and a thickness of ·002 millimètre. Under the microscope they appear grouped together without order, or piled one upon another like pieces of money, and are of a red colour in reflected light. The *white corpuscles* are smooth, spherical, of a yellowish-white colour in a reflected light, and from ·008 to ·014 of a millimètre in diameter.

The colour of the blood is a beautiful crimson red in the arteries, but of a darker colour in the veins. We shall have occasion to examine it from this point of view in treating of the circulation.

When blood which has been drawn is allowed to stand in the vessel, it separates into two distinct parts: the one, semi-solid, is called the crassamentum—the clot; the other fluid, is called serum. The clot is the coagulated fibrine which carries with it the red globules which were held in suspension in the blood. When the coagulation is delayed, these globules, being heavier than the other portions of the blood, fall toward the lower part of the vessel; and the fibrine, freed from them, coagulates and retains its own proper colour, and the clot is composed of two layers the superficial layer is of a grayish or white colour and semi-transparent, and is termed the "buffy coat." It is formed of pure fibrine mingled with the white globules; the other is composed of fibrine and of the red globules which give it its colour. The serum is a transparent, greenish-yellow fluid, sometimes a little whitened by minute fatty specks; from which circumstance, and from some other points of analogy between them, it has

been called the *whey*. It is a little less dense than the clot, and contains among other principles a great deal of albumen. The serum is the plasma without the fibrine.

The *chyle* is a white opaque fluid closely resembling milk, which is separated from the food during the process of digestion, and is drawn by the chyliferous vessels from the surface of the smaller intestine, and serves to form the blood. As it advances toward the point where it mingles with the blood, it resembles this fluid more and more in its composition; it takes a roseate tint, and, if left to itself, it separates into fibrinous clot and albuminous serum.

The *lymph* is a clear, transparent fluid, slightly tinted with green or yellow. Drawn from the organs by the lymphatic vessels, and especially from the skin and the surface of the mucous and serous membranes, the lymph is poured into the mass of blood by two principal canals. Like the chyle it contains white globules and minute specks of fat. When extracted from the lymphatic vessels, it also separates into fibrinous clot and serum, containing a little albumen.

We see therefore that chyle and lymph are imperfect blood. The chyle leaves the digestive apparatus in a crude state, and goes to the blood-making laboratories for its perfection. The lymph comes from the extreme limits of the organs to these same laboratories, and, uniting with the chyle, is poured into the blood—the constituent fluid *par excellence*.

The secreted fluids or *secretions* are produced by special apparatus from the materials furnished by the constituent fluids. They differ from these last in being only a medium for the elements which they hold in suspension, these elements not being essential to them, as the globules are to the blood, for example. They all contain one or several organic fluid substances, to the nature of which the secreted fluid owes its essential properties. These humours are very numerous, and play a very distinct part in the human economy. They are normal or morbid, as they owe their origin to the regular function of the organs or are modified by the action of disease. We shall mention only milk, which resembles the blood by being composed largely of serum, and which cannot be

replaced by any substance for the alimentation in the first stages of infancy;—the *aqueous* and *vitreous* humours of the eye, the *synovia* which bathes and lubricates articulated surfaces, the *tears*, and the *saliva*, which we shall see later takes a part in digestion, and in which Mons. Longet has shown the existence of minute and therefore harmless proportions of *sulpho-cyanide of potassium*, one of the most virulent poisons. In popular language the term *humour* is applied exclusively to the purulent fluids, morbid products which differ in some particulars according to the conditions under and the organs in which they are formed. It is unfortunate that they should monopolize a term which belongs to all the organic fluids.

We shall merely point out the *intermediate products*, among which figures the *chyme*, a semi-fluid substance formed in the stomach during digestion, and the *excretions* which the system rejects, after having separated from them nearly all assimilable principles.

The *tissues* are the solid parts of the body, formed of anatomical elements either bound together or simply in juxtaposition. The tissues are classed according to the elements peculiar to them, according to their texture, that is to say the mode in which these elements are arranged; and according to their essential properties, which are either physico-chemical, such as consistence, extensibility, retractility, elasticity, and hygrometricity, or organic, like the properties of absorption, of secretion, of development, of regeneration, of contractility, and of innervation. These properties are variable according to the tissues, which are more or less tenacious, more or less extensible, and so forth. Or they are peculiar to certain tissues, and independent, for a tissue may be retractile and not extensible or elastic, and *vice versâ*. *Constituent* tissues are those which, composed of the fundamental elements, fibre, cell, and tube, form the essential organism. *Produced tissues* are those which emanate from the first, and may be detached from them without destroying them, and are only accessory or complementary parts. These products are normal or morbid, according to their nature and substance.

Among the numerous tissues which exist in the economy we cite the following:—

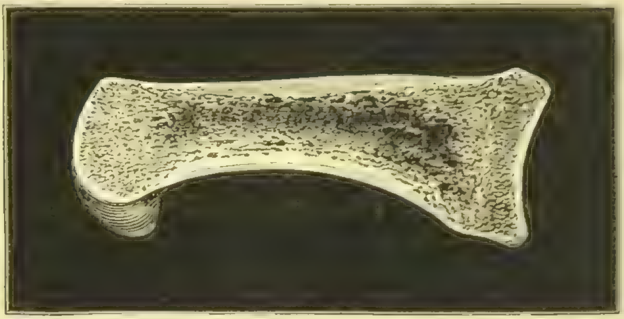


Fig. 2.—Bony tissue as seen with the naked eye.

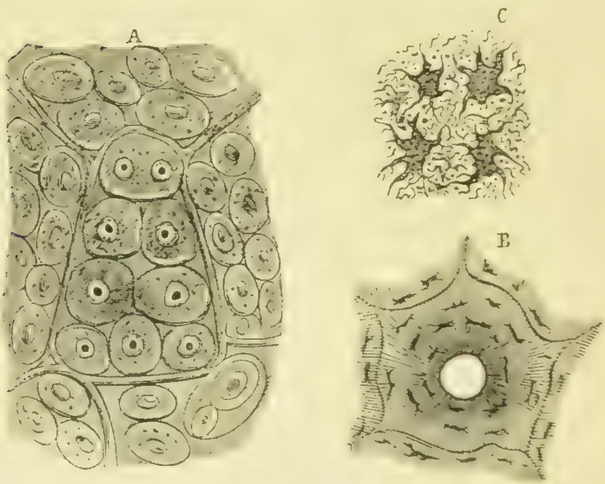


Fig. 3.—Osseous and cartilaginous tissues as seen through the microscope.

A, *Cells of cartilaginous tissue.*
B, *Section of a canal of Havers, showing the disposition of the starry cells in the substance of a bone.*
C, *Starry cells magnified.*

Osseous or bony tissue, which is composed principally of an anatomical element called *osteoplasm.* It is compact in

some parts of the bones, and spongy in others. This tissue is traversed by infinitely ramified conduits, called the *canals of Havers*, which contain the blood-vessels and the medullary substance or marrow.

Cartilaginous and *fibro-cartilaginous* tissue.

Cellular or *connective* tissue, more exactly named *laminated* tissue, formed of laminated fibres, long, flattened, undulated filaments in bundles, and of fibres appertaining to elastic tissue. In nearly every part of the body this substance fills the spaces between the tissues or between the bundles of the fibres of which they are made up: on the surface of the body and of its cavities, and around the organs, it is disposed in enveloping membranes.

Adipose tissue is formed of cells or vesicles containing fat. It is never found except in the cellular tissue and at the points where this last is least dense.



Fig. 4.—Laminated fibres in the first stage of development.

These two tissues united are commonly designated by the term *fat*, or *fatty layer*, but they are distinct notwithstanding, and neither wasting nor increase of fat causes any change in the mass of the cellular tissue, but only in the *quantity* of fat contained in the cells of the adipose tissue.

Epithelial tissue has for its anatomical elements, cells or free nuclei, which form by juxtaposition either a very thin single layer, or several superposed layers. It is of this tissue that the epidermis and the epithelium, a kind of internal epidermis, are essentially composed.

Muscular tissue. This constitutes the muscles, or the flesh, properly speaking. It is composed of elements called *muscular* fibres, which are of two sorts, the *smooth*, formed of fibre-cells, and the *striped*, formed of bundles of fibrils. The fibrils are the fundamental element of the muscular tissue; their primitive microscopic bundles unite in secondary bundles visible to the naked eye, and are known in

descriptive anatomy under the name of fibres of the muscles. The fibrils are contractile but not elastic, and their primitive bundles have a homogeneous envelope of elastic but not contractile tissue called *sarcolemma.*



Fig. 5.—Striped muscular tissue as seen under the microscope.

A, *Fibril deprived of the sarcolemma, to show the disks of which it is composed.*
A′, *One of these disks.*
B, *Several fibres less magnified.*

Fibrous tissue has the same elements as the cellular tissue, united in compact bundles visible to the naked eye, strongly adherent among themselves, and interlaced in every direction. Fibrous tissue is found especially in the articulating and interosseous ligaments and in certain enveloping membranes, as the sclerotic, for example, which forms the white of the eye.

Tendinous and *aponeurotic* tissue is made up of a variety of very thin laminated fibres, with puckered edges, undulated and adhering directly at one extremity to the sarcolemma of the striped muscular fascicles, and to the osseous substance at the other. These fibres unite in little flattened polyhedral bundles, from ·001 to ·002 of a millimètre in breadth, from which the tendons and aponeuroses, which are of a tendinous nature, are formed. Tendinous tissue is inextensible lengthwise, and inelastic.

Nervous tissue is essentially formed of tubes, which are large and small. They have homogeneous, thin, transparent walls, and contain a viscous, fatty fluid, which is the *medullary substance* or the *white substance* of Schwann, in which there is a sort of stem—the *axis-cylinder.* In the spinal marrow and in the brain the walls of the tube are wanting, and only the medullary substance and the axis-cylinder remain. As we approach the outside of the body we find, on the contrary, that the tubes

become more homogeneous in structure, until at their extremity they are reduced to a filament in which the walls, the

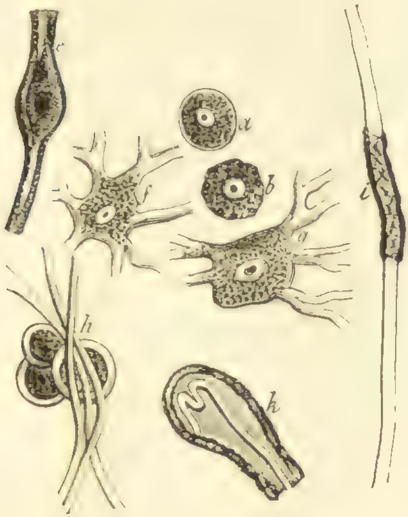


Fig. 6.—Nervous tissue seen under the microscope.

a b, *Spherical nerve-cells.*
e, *Bi-polar cell.*
f g, *Multi-polar cells.*
h, *Cells of the ganglia and nerve-fibres.*
i, *Nerve-tube and axis-cylinder.*
k, *Termination of a nerve-fibre in an organ.*

cylindrical axis, and medullary substance are not distinguishable. At certain points of the nervous system the tubes differ anatomically, according as they belong to the nerves of sensation or the nerves of motion.

Other elements also are found in the nervous tissue—the *ganglionic cells* or *corpuscles*, and the *fibres of Remak.*

The *ganglionic corpuscles*, so called because they are found in the substance of the ganglia, receive the sensitive tubes as they come from the brain or spinal marrow. These tubes unite with the walls of the corpuscle at one of the points or poles of its periphery, and emerge from it at the opposite pole.

The ganglionic corpuscles are divided into bi-polar or multi-polar, according as they receive one or several tubes.

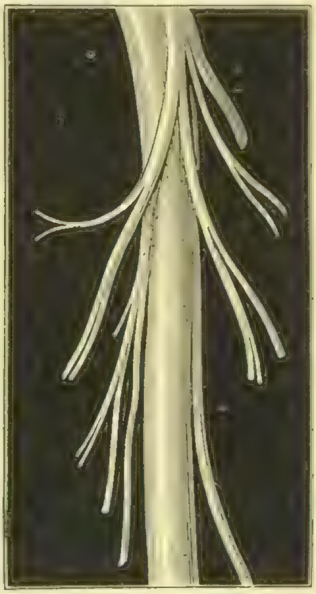


Fig. 7.— A nerve and its ramifications seen by the naked eye.

The *fibres of Remak* appear to be one of the constituent elements of the filaments of the nerves of motion.

CHAPTER II.

Form of the body—its beauty.—The master-pieces which it has inspired.—Description of the skin—its functions.

Nature, in modelling animals, has marvellously adapted their forms to the functions and to the mode of life to which she has destined them; but no creature has received in the same degree as man, that mingling of strength and of elegance in contour, of grandeur and delicacy in the lines, and in no other has she taken such care to distinguish the two sexes in bestowing upon them her most precious gifts. It is of the human race alone that Buffon could say: "Man has strength and majesty; beauty and the graces are the dowry of the other sex."

The fabulist, using the poet's privilege, makes the lion say—

> "Lions might hold the upper hand,
> If they but had the art to paint."

Doubtless in comparing himself with certain animals, man cannot ignore his inferiority in muscular strength and in the arms which nature has given him; but what matters it? He feels his superiority to these beings, though they are stronger and better armed than he. He knows how to avoid their attacks and to triumph over their brute force. He constrains them to his service, and disposes of their lives and of their bodies, by obeying not a blind instinct but the voice of reason. If he believes himself first among the dwellers on his planet, it is not his vanity which persuades, but his intelligence that proves it to him, and gives him the right to treat all other creatures as their master.

We admire the majestic bearing of a tree, the elegance of

a flower, the plumage and flight of a bird, the stately tread of some huge mammal, but nothing impresses us so much as the human form. It is not from sympathy with beings of our own species that we find them more beautiful; the judgment that we pronounce upon their beauty is not due to the inclination of one sex to the other; this sympathy and this inclination are common to most of the superior animals, but man alone appreciates the difference between individuals as between species; it belongs to him only to class them according to their merits, and to distinguish perfection from deformity; he alone possesses the sentiment of the beautiful, that faculty which permits him to admire the Creator in his works, and gives him the right to place himself in the first rank of animated beings.

The plastic arts receive their most elevated inspirations from the human form, and it is to the efforts of painters and sculptors to reproduce it in its perfection that we owe the treasures of our museums. It is often said of these master-pieces that they are the ideal of beauty, but we are not to understand from that something superior to nature itself. The artist may appreciate the relative beauty of the models which offer themselves to his eyes, but in ceasing to follow nature and in endeavouring to become her superior, he could only bring forth an imaginary product, a monstrosity. Anatomy should be his first study; if he forgets its precepts he becomes incorrect, like the musician who offends against the laws of harmony. The ideal is not therefore a form more perfect, it is the perfection of the natural form itself which the artist strives to attain, either by drawing inspiration from a single model, or by uniting in a single figure all the details which he has borrowed from different individuals. Far from seeking to surpass nature he feels that his hand is powerless to render completely the impression which his practised eye receives.

Within certain limits he may nevertheless exaggerate or weaken some detail of form, and that too without ceasing to imitate nature, who shows him in this manner how he may embody the character and the physiognomy. The painter and the sculptor therefore may rightly allow themselves a certain latitude in lines and proportions; it is a poetical



Fig. 4.—Apollo Belvedere.



Fig. 9.—The Venus of Milo.

license, analogous to that which allows a musician to obtain grand effects by momentary discords. To us then it seems that in questions of this nature the critic should proceed with a great deal of reserve. The right of the anatomist to point out an irregularity cannot be contested, and the artist should be warned that to genius alone can such be permitted; but even if we admit that all the criticisms addressed to painting or to sculpture in the name of the natural sciences are well founded, who could, in the presence of a master-piece, obstinately dwell upon a fault of detail?

As regards the inspiration drawn from the human form, the beauty of Raphael's Madonnas and the admirable paintings of the Venetians impress us perhaps still more than statuary. Under the pencil of the great masters it is man himself that we see. What is more beautiful than the "Vierge à la Chaise," or than that "Violante" painted by Giorgione, of which Venice formerly possessed the glowing figure?

In sculpture the form alone is seen, painting adds the illusion of colour and the transparency of tone; the figures of the statuary have exactness in movement and flexibility of form, the painter vitalizes his creations, gives light and life to the eye, and makes the blood circulate through the skin, which he seems to steal from the living model.

The *skin* is a membraneous tissue, resistant and flexible, varying in density and thickness according to locality, which covers the whole body and completes the form by softening the contours. It adheres to, and is intimately united with, the subcutaneous cellular tissue by fibrous prolongations. At some points it receives aponeurotic insertions, as in the palm of the hand and the sole of the foot; at others, as on the neck, for instance, the muscular fibres are attached to the skin, and mingle with the fibres of its deeper layer. There are folds in the skin, sometimes temporary and at others constant, which result from the flexion of the parts or from the contraction of the muscles, becoming more marked with age, and more or less numerous and profound as the subject is inclined to leanness or to obesity.

The skin slides over the organs within certain variable

limits, according as the cellular tissue which it carries with it is more or less relaxed, and as it is itself thick or thin. Thus it is movable on the back of the hand and top of the foot, on the front of the neck and on the surface of the joints; it is almost immovable on the cranium, on the palm of the hand, and on the sole of the foot.

Elastic, very extensible, and very resistant, it sustains, without being torn, violent shocks and great compression; as in certain wounds by firearms, for instance, the projectile will penetrate the clothing to the skin, and injure the organs which it covers without itself being broken.

The skin is the organ of feeling, its surface is endowed with a sensibility which becomes extremely delicate at several points. Being constantly in more or less intimate contact with the atmosphere, it transmits to the economy the influence of external agents; and it is partly by its tissues that the fluids and gases are eliminated, which have done their office, and are to be thrown off as the ultimate and abandoned products of nutrition.

This function of continual exhalation makes the skin the regulator of the temperature of the body. When the temperature of the organism is elevated either by motion or any other internal or external cause, the sweat immediately appears, and the cooling or loss of heat caused by its evaporation reduces the temperature to its normal standard. Lavoisier was the first who clearly explained this function, so important from its utility, and from the serious consequences which result from its disturbance.

Almost entirely deprived of the covering which nature has given to animals, the colour of the human skin exhibits the richest and greatest variety of shades. This colour is incessantly modified by the sensations, the movements, by moral or physical emotions; and the transparency of its tissues give as much delicacy as vigour to the tones which animate it; it is not, as in the plumage of birds or in the shells of molluscs, an assemblage of brilliant colours, often without transition, but it is a blending at once the most harmonious and the most striking; it is light in its softest changes, in its most dazzling splendour.

On examining the thickness of the skin, we first find on the surface a thin transparent membrane, a sort of organic varnish, designed to receive the contact of the air and of external objects. This is the *epidermis.* Elastic and very

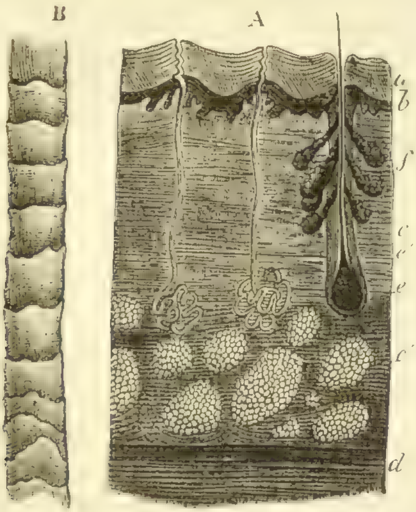


Fig. 10.—The Skin.

A. *Section of skin under the microscope.*
a b. *Superficial and deep layers of epidermis.*
c. *Dermis—true skin.*
c'. *Fatty areas of the deeper portions of the dermis.*
d. *Muscular layer subjacent to the skin.*
e e'. *Sweat glands and ducts.*
f. *Hair-follicle and sebaceous gland.*
B. *Hair seen under the microscope.*

flexible, it lends itself to every movement of the skin, protecting its exquisite sensibility and modifying its property of rapidly absorbing gases and soluble bodies. Although this membrane is so thin, we can discover a superficial or *horny* layer and two deeper layers. The first, the true epidermis, thickens and becomes callous under the influence of rubbing or pressure, as for instance on the heel. The other two layers are the *mucous network* of Malpighi and the *pigmentary layer.* It is in the substance of this last especially that the *pigment*, the colouring matter of the skin, is developed.

It is a black or brownish substance, more or less abundant according to the region of the body, individual, or race, but constantly existing in normal conditions, alike in Europeans and in the people of Soudan and Australia. The presence of this pigment and its unequal distribution contribute to the variety of complexion exhibited in the white race.

Under the pigmentary layer is the *dermis*, the thickest and most resistant part of the skin; it is white, semi-transparent, and is composed of fibres of cellular tissue, fasciculated and very dense; of elastic fibres, ramified and disposed in network; and of contractile fibre cells.

Immediately under the epidermis the surface of the dermis is covered with *papillæ*, little conical or rounded elevations formed by the extremities of the nerves and vessels, which are divided into nervous papillæ and vascular papillæ. Each nervous papilla is surmounted by an organ, which from its function and its microscopic dimensions is called a *tactile corpuscle* or corpuscle of touch. They are much less numerous than the other papillæ, and are not found everywhere on the skin. They are seen on the palm of the hand and on the lateral and palmar surfaces of the fingers, on the sole of the foot, on the tongue, the lips, and some other points. The epidermis follows exactly the shape of these papillæ, and thus forms, in tracing the furrows which separate them, those graceful meandering lines and elegant curves which we see especially on the palm of the hand. Very dense at its thickest portion, the structure of the dermis grows more relaxed on approaching its lower face, and forms spaces or areolæ in which adipose tissue is developed, and at last it intimately unites itself to the subcutaneous cellular tissue, from which the dermis receives, and to which it sends, fibrous prolongations.

Gratiolet is inclined to admit that these so-called nervous papillæ are almost entirely wanting in nerves. He compares them to little keys, so to speak, pressing lightly on a very sensitive surface, and leaving there only very limited impressions.

Other connections also exist between the tegument and the subcutaneous cellular tissue: these are the nerves and

the lymphatics and blood-vessels, which arise from the skin or terminate in it; and the follicles or glands, which are situated in the substance of the dermis, according to most authors, but in the subcutaneous adipose tissue, according to Robin. These send the product of their secretions by special ducts to the epidermis. These ducts traverse the substance of the skin sometimes in straight and sometimes in twisted lines, and give passage, some to hairs, to the beard and to products of this nature which are formed in the bulb of the hair-follicles; and others, to the secretions of the *sweat-follicles* and the *sebaceous glands*. The orifices of the sweat-follicles, situated at the base of the papillæ, exhale the secretion in the form of insensible perspiration, or in the form of little drops on the surface of the skin. Those of the sebaceous glands open, some into the hair-ducts, and others on the surface of the epidermis, and furnish to that membrane and its dependencies a fatty substance which seems to be designed to preserve the softness of the skin, and to protect it from injury or change from the sweat; we find them therefore in the greatest abundance at those points where the transpiration is most active.

Of these glands and follicles of which the microscope shows us the details, some attain the size of a grain of millet, but most of them hardly reach a millimètre in diameter. Their orifices are on the surface of the epidermis, a point long disputed, but now admitted by anatomists. But these orifices are not what were formerly denominated *pores*. It was supposed that there were gaps or spaces in the skin analogous to those in a sieve, and that the cutaneous secretions issued from these gaps; but neither in the epidermis nor in the skin are there any such gaps, and it will be seen from the preceding description wherein the doctrines of the ancients differ from, and wherein they resemble, those of our own day.

The epidermis is regarded by anatomists as impermeable, and yet experiment proves that even the perfect skin allows gases and fluids to penetrate the organism. If we do not admit that this absorption takes place through orifices at the surface of the epidermis, and if we suppose it to take

place by imbibition or endosmosis, it is plain that the skin is permeable, at least under certain conditions. But it is not equally so throughout its whole extent; the thicker the epidermis the slower and more difficult is the absorption; in short, the skin, like all the other tissues, absorbs certain substances to the exclusion of others.

We shall have occasion to discuss these phenomena in treating of absorption.

After enveloping the body, the skin folds back upon the openings which give access to its cavities, and modifying its nature, becomes, under the name of the mucous membrane, an internal skin, analogous, as we shall see further on, to the external skin in its structure, its functions, and in the intimate connection which is established by their reciprocal influence and unity.

CHAPTER III.

Structure of the body.—Bones, cartilages, joints—Muscles, tendons, aponeuroses.

Bones.—The bones are the framework of the human body. They are formed of a hard and extremely resistant tissue, and they surround more or less completely with solid walls the cavities containing delicate organs; they provide attachments and support for the soft parts, and furnish a fulcrum for the movements of the body; and lastly, by their resistance they permanently maintain the proportions between its different parts.

The osseous substance is composed of calcareous salts—phosphate or carbonate of lime—intimately combined with organic principles, the decomposition of which produces gelatine.

If the bone is immersed for a length of time in hydrochloric acid, the calcareous matter will be dissolved, and the isolated gelatine will retain perfectly the form of the bone; and in the same manner if the gelatine be destroyed by combustion, the lime which remains will show the normal form and dimensions of the bone. In a gelatinous state the bone is soft and flexible; in the calcareous state it is hard, rigid, and brittle; in a normal condition each of these constituent substances serves as a corrective to the other; and their properties united give to bone its solidity and its elastic resistance.

In the osseous tissues, as in all those of the body, we recognize a movement of composition and of decomposition, of molecules assimilated and again rejected after a certain time; but in none of the organs so well as in the bones has it

been possible to demonstrate this double movement of nutrition. If we mingle madder with the food of an animal, the bones soon become red, and they regain their original colour when the colouring matter ceases to form part of the food. Or, more conclusive still, if the madder be given for a while and then omitted, and after a time be again given, the bone show a white layer between two red ones, which proves that they grow from the circumference toward the centre, by the ossification of the deepest layers of the periosteum.

The bones are divided according to their form into long, flat, and short bones. The *long bones*, which are first and most rapidly developed, are more dense in the middle or body of the bone than at their extremities. This body is formed principally of a compact bark or rind of ivory-like tissue, and is pierced throughout its length by the medullary canal; the extremities are composed of spongy tissue enveloped by a thin layer of ivory tissue. The long bones combine to form the limbs and the thorax; designed to serve as levers or columns, they are twisted on their axes or bent so as to offer the greatest possible resistance in exerting a force or supporting a weight.

The *flat* bones form the walls of the cavities of the cranium, of the chest, and of the pelvis; they are thinner in the middle than at the edges, and are composed of two leaves or tables of ivory tissue resting upon and confounded with each other at some points, and separated at others by a layer of spongy tissue.

The *short bones* are very irregular in form and difficult to describe; very spongy in texture and relatively light. They develop later and more slowly than the others, and they are placed in groups in parts of the body where the bony frame must possess a limited power of motion, and yet be very firm, as in the foot, in the hand, and in the spinal column.

There are 198 bones in the human skeleton when it has reached its perfect development. On the surface of the bones, and especially at the extremities of the long ones, there are prolongations of different forms, designed either to join the bones together, or to serve for the attachment and insertion of muscles or ligaments. These prolongations are



Fig. 11.—Skeleton.

the *apophyses*, which are distinguished by anatomists by names suggested by their position, by their use, or borrowed from objects of which they recall more or less exactly the form.

The body of the long bones and the central part of the large bones are developed before the extremities and the edges. The extremities of the long bones are cartilaginous in early life, their articulating surfaces are formed of cartilage adherent to, but not continuous with, the bone to which it belongs. This is the *epiphysis*, which afterward becomes ossified, but is not perfectly united to the bone till about the age of twenty. Some of the large bones also present *epiphyses* on their edges or borders.

A white fibrous membrane, resistant in youth and reduced to a thin layer of cellular tissue in the adult and aged, which is called the *periosteum*, envelops every part of the bones, except where they are covered with cartilage and where the tendons and ligaments are attached. The periosteum adheres closely to the bone, and distributes a network of vessels through its substance. Recent surgical investigations have shown that the periosteum plays an important part in the partial reproduction of the bone after certain operations.

Cartilage.—To the bony system belong the cartilages, which are formed of what might be termed tissue in a state of transition between fibrous and bony substance. This tissue, homogeneous in true cartilage, mingled with fibrous substance in the fibro-cartilaginous parts, is elastic and flexible, and in colour either yellowish or pearl-white. The cartilages unite the bones at those points where, as in the chest, the bony frame must yield to expansive movements; they furnish a flexible skeleton to certain organs, as the external ear, for example, the nose, the eyelids, and the larynx; and lastly, they play an important part in the joints.

No part of the organism shows more clearly than the bony system the care which nature has taken to provide during infancy the gifts of which she is so prodigal in maturity, and which she withdraws little by little in old age. During infancy, when protected by maternal care and when the growth should be rapid, the gelatine predominates in the bones;

they are flexible and have only a resistant power proportionate to the movements and efforts of infancy; it is the branch full of sap, but of which the woody portion is not yet developed. In youth, as the muscular power augments, the bones gradually become more solid; the extremities, at first cartilaginous, become ossified; the epiphyses unite with the body of the bone; and the articulating cartilages gain more consistence. In the adult at last the bones are complete. They are able to resist the muscular efforts of maturity, and perform their functions perfectly, like all other parts of the organism which are fully developed. But age approaches, the strength decreases, nutrition falls off, the bones become more solid, their power of resistance lessens, the medullary canal enlarges, the proportion of calcareous salts in the osseous substance augments, the bones are harder but they are also more brittle. Thus, as each phenomenon of life is linked with every other, we find the bones of a child quickly and easily restored if broken; in the adult the process may be longer, but is generally easy and complete: in the old man the reunion of the fragments takes place slowly, and sometimes cannot be effected at all. The delicate twig, which afterwards became a vigorous branch, is now dry and destined to speedy decomposition.

Joints.—The bones are attached to each other, either by their extremities or their sides, in such a manner as to permit freedom of motion to a greater or less extent between the different parts of the skeleton and of the body. Held together by a sort of cog-wheel system, by the fitting of a projection into an appropriate cavity, or by juxtaposition, they are maintained in connection either by the reciprocal attachments of these projections, or by envelopes—the *articular capsules*—and by *ligaments*, constant in their nature, but varying in form and disposition, according to the different movements which they are designed to permit and insure.

This assemblage, this connection of the bones, is termed a *joint*. Joints are classed according to the form of the articulating surfaces, and according to the extent and variety of the movements produced by them. The bones of the

skull are attached by the notches on their edges; these are termed the *sutures* of the skull. They ossify with age, and may be considered temporary joints, or rather a transition between the separation of the bones and their unification. The other joints, on the contrary, are permanent, and designed to leave to the bones which they unite a mobility which continues during life.

In some of the joints the surfaces are nearly plane or flat; others present projections with corresponding depressions; sometimes there is a segment of a spheroid upon which the cavity which receives it moulds itself; sometimes a cylinder which turns upon its axis in a ring, or a pulley-groove around which slides an apophysis, or a mortise in which a tenon is set.

Here, as in all the works of nature, we admire the inexhaustible variety of form and of mechanism. Doubtless there exists between certain articulations resemblances which permit them to be classed together; but all are as distinct as the bones which they unite, and like them present diversity of character. Separately considered they astonish us no less by the multiplicity of detail in their mechanism, whether we examine the most complex or those whose surfaces present the least irregularity. In fact we nowhere find a uniform plan, and the projections as well as the depressions are curved in the most capricious manner.

These details of the general outline belong to no precise geometrical form; they are neither cubes nor spheres, neither cylinders, cones, nor pyramids, although in anatomical language these terms are applied to them. There is an assemblage in the same apophysis, or in the same cavity, of curved surfaces borrowed from the most widely differing solids, united under angles the most varied, and modelled on sinuosities which defy geometrical description.

In addition to these distinctive characters of the joints, we may mention others which are common to them all. All the joints have cartilages covering the bones which form them; all are kept together by special ligaments, and are lined with a synovial membrane, whose functions we shall subsequently describe.

The polish on the *articular cartilages* facilitates their sliding over each other, and lessens the friction of the bony extremities, while their elasticity diminishes the pressure and deadens the shocks to which the joints are subject. The thickness of these cartilages is proportioned to the motion and the pressure which they are designed to support, and it is greatest at the centre of the convexity of protuberances and on the borders of cavities. The articular cartilages never ossify, differing in this respect from those which, as in the thorax for example, maintain continuity and play the part of flexible bones. These last are *ossifying cartilages*. The others differing in structure, being without vessels, have been compared to the enamel on the teeth. In fact, they are composed, like that enamel and some other analogous productions, of an almost inorganic substance, and mechanical injuries are the only ones which they have to fear.

Wherever in the organism surfaces move over each other, they are covered with a membrane which secretes a fluid, differing in quality according as there is a sliding or rubbing of the organs. In the interior of the joints the membranes are termed *synovial* membranes, and secrete a fluid called *synovia*, because its physical characters resemble those of the white of an egg. The synovia is to the joints what oil is to the wheels of a machine; incessantly poured out upon the surfaces, it lubricates them, and renders the movement, already so easy owing to the polish of the cartilages, still more so; it increases the suppleness and elasticity of these last, which if they were not supplied with this oily fluid would soon be worn out, and motion would be impossible. This sometimes results from certain diseases, and sometimes also in old age.

We have said that the joints are united by *ligaments*. This term is applied to the bands or membranes composed of fibrous tissue, flexible and inextensible. The ligaments, which are in the form of bands, are sometimes parallel and sometimes interlaced, and placed either between the articular surfaces or around them. In the latter case their internal face is covered with intimately adherent synovial membrane. The ligaments are attached to the bones at a

greater or less distance from the articular cartilage, and they adhere so strongly that it is easier to break the bone or the ligament than to tear it from the spot where it is planted. The membranous ligaments—capsulary ligaments or fibrous capsules—are like a circular band of which the two openings are fastened to the bones which they unite. The fibrous pads or cushions which run round the circumference of certain articular cavities are also considered as ligaments. They increase the depth of these cavities, and give greater

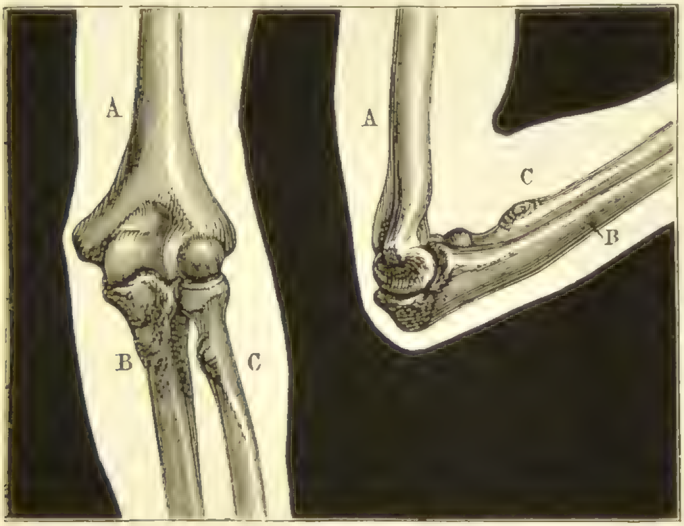


Fig. 12.—Elbow-joint.
A. *Humerus*. B. *Ulna*. C. *Radius*.

solidity to their borders, upon which the osseous extremity received there exerts considerable pressure.

Such is the assemblage of apparatus comprised in the joints. The most perfect machine which man has ever been able to construct bears no comparison to the admirable mechanism of which we have just endeavoured to give a general idea, in the precision, delicacy, and variety of their organs or of their movements. Even in their most complicated parts, machines invented by man offer nothing but

a simple mathematical precision, impossible to mistake, because all the surfaces are conceived and traced out geometrically. In the joints, on the contrary, all the lines and surfaces are vague and uncertain; and when we examine an articular extremity, the inferior extremity of the humerus for example, we shall at first be tempted to believe that the unsymmetrical projections and depressions, the incomplete grooves, and the undefinable irregularity of the whole, belong to a work spoiled or modelled at hazard by a confused mind; but on seeing the action of the elbow-joint when laid open by the anatomist, we discover that it is to this very irregularity of the bony extremities, to the multiplicity of detail, to the absence of symmetry, and to the more or less limited extent of their articulating surfaces, that the variety of movement is due, and we cannot sufficiently admire this assemblage, so complex, but yet so justly calculated to give to the movements of the fore-arm the greatest precision, strength, and rapidity, and to combine these movements with those of the arm and the hand.

And if we pass from the most mobile of these joints to those not at all or only slightly movable, the perfect coaptation of their surfaces, their powerful methods of union, the unity of movement of the bones, whether they take part in the motion or serve only as fulcrums, all seem to be as simple as possible in function, although the whole as well as the details presents the most delicate application of the laws of mechanics and statics. We may add that here as well as everywhere in the study of the works of nature, we see the organs develop themselves from the embryonic state to that of perfection, under the influence and in the exercise of their functions. But leaving out the inimitable results produced by *life* in natural creations, and considering them as inorganic bodies, the mechanism of the joints leaves far behind all the most ingenious productions of art or science.

The distance appears to us greater still when, instead of a combination of surfaces and the method of their union, we study the action of the muscles and the transformations which are incessantly taking place in the organs of digestion and respiration. In unveiling a part of these mysteries to

man, the progress of science only increases his admiration. What would it be if life, that force of which he is conscious, and which he shares with all organized beings, should cease to be to him an impenetrable secret!

Muscles.—United by the joints, the bones of the skeleton, taken as a whole, approach the form of the body. But in order to put these bones in motion, and to bring these joints into play, we must call to our aid an external force. By itself, if we may be permitted a very familiar comparison, the skeleton is a puppet of which the different parts are put in motion by threads. The threads by which the skeleton is moved are the muscles. The name *muscles* is given to the masses of red tissue which constitute the flesh. We have already described the elements of the muscular tissue; how the primitive microscopic bundles, united into secondary ones, become muscular or fleshy fibres easily distinguished by the naked eye. These fibres are parallel or divergent according to the muscle, and assume different forms. Sometimes it is that of a ribbon (sartorius, sterno-hyoid, &c.); sometimes a broad web-like tissue of a texture more or less firm, like the transverse muscles of the abdomen; in one region the muscle, swollen in the centre, and drawn out like a thread at the ends, resembles a spindle in form (biceps, straight muscle of the thigh); in another it is fan-shaped (temporal, obturator), or like a ring (orbicular muscle of the lips and eyes); or the fibres converge like the radii of a circle (the diaphragm); or are disposed in parallel lines like



Fig. 13.—Biceps muscle of the arm.

A. *Body of the muscle.*
B. B. *Superior tendons.*
C. *Inferior tendons.*

the feathers of a pen (extensor muscles of fingers). Lastly, certain organs, the heart for example, are nothing but muscle, or rather an assemblage of muscles intimately united.

The muscles determine the form and volume of the body, and especially of the limbs. The outline depends upon their projection, and changes incessantly as they are in action or in repose. They are disposed in layers, deep or superficial, and united in groups or separated by sheaths and membranous partitions. Their colour varies from deep red to pale rose, according to the region of the body they occupy, age, sex, the constitution and richness of the blood. The stronger the muscle the redder it is, and it becomes still brighter under the influence of exercise.

The muscles of the human body number about 350, and they are distinguished by names suggested by their form, their locality, their functions, or their attachments. Some are fixed to the skin, as several of the muscles of the face: others to muscles in their vicinity, as in the face and tongue; others still to the cartilages, but the largest number to the bones by means of the tendons or the aponeuroses, of which we proceed to speak.

Tendons, aponeuroses.—In most of the muscles we can distinguish a fleshy portion, which is essentially the muscle, and a fibrous portion, which is called either *tendon* or *aponeurosis* according to its form. The tendons are fibrous cords of variable length, rounded or flattened, of a pearl-white colour, attached to the bones by one of their extremities and united to muscular fibres by the other. The aponeuroses are nothing but large thin tendons, a kind of fibrous web or band which accompanies the muscles, separating them by partitions or enveloping and uniting them in bundles. The tendinous fibres are generally developed in the substance of the fleshy part of the muscle, or on the surface, which they cover to a certain extent. In the first instance they are inclosed, as it were, by the muscle; in the second, they envelop it like a sheath. This reciprocity gives great solidity to the whole.

The muscles and tendons are united together by the direct adherence of the extremities of their fibres, which takes place

in right lines; or by the insertion of the fleshy fibres at some point in the length of the tendon, at various angles, but never exceeding 45 degrees. Such is the force of this adhesion between the two tissues that rarely if ever does external violence or the greatest effort succeed in overcoming it, the tendon or the muscle breaks before separating at their points of union. We have already pointed out, in speaking of the articular ligaments, the remarkable fact that the adhesion of two organic tissues is stronger than the cohesion of either of the respective tissues.



Fig. 14.—Lower portion of the leg.
A. *Tendon of Achilles.*

The tendons and the aponeuroses, though very flexible, are entirely inextensible, and offer therefore great resistance to force applied to their length. This is one of the conditions necessary for the part which they play in uniting the organ of motion and the object to be moved.

Like the ossifying cartilages, the tendons may be considered as a transition tissue. They partially ossify with age at their points of insertion into the bones, but they are never entirely transformed in the human race, as in some animals, the Gallinaceæ for example, into a bony trunk. Suppleness and variety of movement would not accord with this transformation; and among the differential marks which Plato might have added to his famous definition of man, this would have sufficed to prevent Diogenes from saying, as he exhibited the cock stripped of its feathers, "Behold Plato's man!"

A relatively slender tendon suffices to transmit a motive force developed by a certain amount of contractile fibre, and the fleshy portion of the muscles far surpasses in volume the tendons and the aponeuroses. If the muscular fibres attached themselves directly to the bones the surface of the bones

would not be sufficient to supply space for them; the direct attachment to large surfaces is confined to a few only, the others being attached by their aponeuroses or tendons to limited spaces.

The muscles are at the same time contractile and extensible. The muscle shortens by contraction and increases in thickness at the same time that its length diminishes; in repose it is soft and yielding to touch, in contracting it becomes hard and resistant. These successive changes are easily demonstrated by applying the hand to the course of a superficial muscle, on the front of the arm for example, on the biceps. When the fore-arm is extended it projects but slightly and yields to pressure; it swells, on the contrary, becomes resistant, and forms a marked protuberance, when contracting in order to flex the fore-arm.

The contraction of a muscle may also take place without its being shortened. When, for example, the fore-arm is extended upon the arm, if the extensors oppose the flexion by contracting, the biceps and anterior brachial, both flexor-muscles, may contract without their ends approaching each other.

Glisson, Borelli, and other anatomists have supposed that the muscle increases in volume during contraction; but further experiment, confirmed also by those of Prévost and Dumas, has demonstrated that it gains in thickness only what it loses in length, and that there is no change in the absolute volume.

In contracting, the muscular fibres become tortuous and wavy, wrinkles are formed on the surface, a sort of trembling pervades the whole mass, and its temperature is raised. Becquerel and Breschet have observed this increase to reach half a degree centigrade.

To the contraction of certain muscles must correspond the inertia or even lengthening of the antagonistic muscles, as for instance when the fore-arm is flexed upon the arm or the leg upon the thigh, the extensors of the fore-arm and of the leg take part in the movement and lengthen by means of their extensibility. In like manner the muscular texture which forms the walls of certain organs, as of the stomach and intestines, is expanded by the fluids and the aliments, or by

the gases which are developed in them. The flute-player of antiquity kept his cheeks distended by means of a leather strap. Thus there is a constant struggle between the contractility and the extensibility of the muscles. But if, during the contraction of certain muscles, as the flexors of the arm, the antagonistic muscles, the extensors, are relaxed and do not oppose the movement, they regulate it nevertheless by virtue of a property named *muscular tonicity*, which gives to their tissues even when not contracted a certain power of resistance. Thus when a group of muscles is paralyzed, the antagonistic muscles cause by their contraction a jerking movement which has no regularity.

In contracting, the muscles act like levers upon the bones, and therefore just so much less powerfully as they are placed obliquely to the bone. Notwithstanding the larger part of the muscles are attached to the bones at an acute angle, and their direction is very oblique in regard to the lever they are to move. The result is a great loss of force, but this loss is compensated by an increase of volume in the muscles, that is in the number of fibres of which they are composed.

Most of the muscles are subject also to deviations or reflections around the joints. Some even take a direction perpendicular to their original one in turning round bony hooks or in the grooves of the pulleys. The apophyses, or the protuberances to which they are attached, permit them to move at a greater angle and a more favourable one than the initial angle, and this angle gradually increases as the bone obeys the force applied to it; and lastly, the relative direction of the muscle as regards the bone varies according to the attitude. These dispositions of the muscles are always adapted to the kind of movement to be executed, to the extent or rapidity required, or to the force demanded; and they are always so combined as to produce the maximum of useful result. So in flexing the fore-arm, in elevating the arm, the bones act as levers of the third order. The biceps, anterior brachial, and deltoid muscles act as very short levers upon the arm, and their initial direction is almost parallel to the bone, but it soon becomes almost perpendicular to it. In this case extent and rapidity of movement

are important, force is only a secondary consideration. If we wish to raise the body on the toes, motion is more limited but a great amount of force is necessary. The gastrocnemius and soleus muscles, which form the calf of the leg, are inserted by the tendon of Achilles—the largest in the body—to the posterior extremity of the calcaneum (or heel-bone), and perpendicular to its axis; the posterior tibial muscle and the flexors of the toes pass behind the internal malleolus under the calcaneum and under the astragalus, as in the groove of a pulley, and are inserted into the plantar surface of the scaphoid and to the last phalanges of the toes, and these muscles act upon the foot, which serves as a lever of the second order; that is to say, under conditions the most favourable to the power represented by the muscular contraction.

CHAPTER IV.

Spinal column.—Thorax.—Upper limb; shoulder, arm, fore-arm, hand.—Lower limb; hip, thigh, leg, foot.

Spinal column.—The spinal column is the foundation to which all the other parts of the skeleton are adapted. It is composed of seven cervical vertebræ, twelve dorsal and five lumbar vertebræ, and is terminated by the sacrum and coccyx. Throughout its whole length runs the *vertebral canal*, which holds the spinal marrow, and communicates with the cavity of the skull. Each vertebra is composed of a body, two articular processes, two transverse processes, and a spinous process. The *body*, the anterior portion of the vertebra, is cylindrical, and forms a layer of the column. The *articular processes*, placed at the sides, serve to unite the vertebræ together; and the *transverse processes* give attachment to the ligaments, muscles, and in the dorsal regions to the ribs. The *spinous process*, the posterior portion of the vertebra, forms that series of projections which has given to the vertebral column the name of the *spine*. The spinous process bifurcates into two plates which complete the ring or vertebral orifice formed by each vertebra, and the open space in which forms a segment of the vertebral canal. Numerous and powerful ligaments combine to unite the vertebræ. Between their bodies fibrous disks in the form of lentils are placed, which adhere intimately to the articular surfaces; they are formed of concentric layers, and near the centre there is a spongy substance saturated with a fluid analogous to the synovia. These disks or intervertebral ligaments, besides binding together the bodies of the vertebræ, serve

to diminish the shocks and the pressure to which they are subjected from the weight of the parts of the trunk above them. They sink down and become thinner while the body is erect, so that there is a difference in the height between morning and evening of about ·02 or ·03 of a millimetre; but repose in bed restores to the fibrous disks their primitive thickness.

Between the vertebral plates stretch the *yellow* ligaments, remarkable for being formed of an elastic tissue which yields to the movements of the spinal column. Other inextensible ligaments envelop the spine at every point, and give great solidity to the whole. The spinal column has three curves—two backward in the cervical and lumbar regions, and one forward in the dorsal region. The ligaments which unite its layers permit only a slight degree of flexibility in the upper dorsal region, but this is a little more extended at the neck and loins, and powerful muscles give it at need great rigidity. And lastly, to its curves, and to the complicated mechanism of its articulations, it owes its great power of vertical resistance.

The head is balanced upon the first cervical vertebra, which is called the *atlas;* the manner of its articulation with the spinal column permits great extent and freedom of movement, while powerful ligaments and muscles give it great strength.

Thorax.—The ribs are attached by the transverse processes to the dorsal vertebræ, and in front by cartilages to the *sternum* or breast-bone. They are twelve in number on each side. The interstices of this bony cage are filled with muscles; they cover and form with it the walls of the chest, called also the thorax or thoracic cavity, which contains the lungs and heart. The flexibility of the costal cartilages, and the mobility of the articulations of the ribs with the spinal column, allow the thorax to expand and to contract in respiration.

Upper limb.—Near the apex of the cone formed by the chest the upper or thoracic limbs are attached. They are composed of four parts—the shoulder, arm, fore-arm, and hand. The two bones of the *shoulder* are the *scapula*, which

is attached by muscles to the upper part of the back, and the *clavicle* or collar-bone, which extends from the sternum to the scapula, embracing the top of the chest. At the angle formed by the superior border and the external edge of the scapula an articular surface, called the *glenoid cavity*, receives the upper extremity or *head* of the *humerus*, the bone of the arm, which articulates at the elbow with the *ulna* and the *radius*, the two bones of the fore-arm; these form with the *carpus* the wrist-joint, which unites the fore-arm to the hand. The deltoid, the great dorsal and great pectoral, and other less powerful muscles, combine to form the shoulder, and give motion to the humerus. The triceps and biceps of the arm, &c., which surround the humerus, flex or extend the fore-arm and turn it on its axis; and numerous muscles cover the fore-arm and move the hand.

The articulation of the humerus with the scapula or the *shoulder-joint* is, of all joints, the one that permits the most extended movement. The shallowness of the glenoid cavity permits great freedom of motion to the rounded head of the humerus. Thus the arm, which hangs parallel with the body in a state of repose, can be raised vertically to the head, laterally forward so as almost to enfold the chest, and also backward, though in a more limited degree; it can be turned on its axis in all these positions, and in the movement of circumduction it describes a very flat cone, the base of which, especially in front, approaches the apex.

The *elbow-joint* is one of the most complicated in the whole system. The lower extremity of the humerus, and the upper extremities of the ulna and the radius, are adapted to, and interlock with each other by a series of rounded surfaces and pulley-grooves, which permit the fore-arm to flex itself forwards upon the arm; while a protuberance of the ulna, the *olecranon*, which forms the projecting part of the elbow, limits the backward movement by resting in a cavity of the humerus. It is into the olecranon that the tendon of the triceps of the arm, the principal extensor of the fore-arm, is inserted, and we shall see the analogy farther on between this process and the knee-pan.

The movements of the fore-arm singularly multiply by

their application those of the arm. The radius and ulna may be placed in contact with the humerus by flexion, and again the radius turns on its own axis, without either the ulna or the humerus taking part in this movement, which is called *pronation* or *supination*, according as the palm of the hand is turned outward or inward.

But what renders the thoracic limb a perfect organ, that which explains the variety and extent of its movements, and which gives them all their value, is the hand; that admirable instrument which in its perfection belongs only to the human race.

The hand is elegant and beautiful in form. Its isolation, its contour—defined without stiffness—the delicacy of its mould, the mobility of its different parts, and the variety in their tints, make of it a being by itself in the human body, and give it an expression and a physiognomy. Completely developed even in infancy, it presents a most attractive model and an inexhaustible subject of study to the artist. Its structure has led many philosophers to think that it is to it alone that man owes his superiority to the animals, and to attribute to it the greatest influence over the intellectual faculties. But the study of man shows that we must reverse this proposition. The hand is only the instrument of the intellect, the perfection of the one is necessarily dependent upon that of the other, and the hand of man, like every other part of his being, has no equal in the animal kingdom.

As for seeing in the greater or less perfection of the hand a sign of the degree of intelligence, and carrying it so far as to distinguish between the hand of a man of talent and genius, and that of a fool or a man of moderate ability—this is a theory which, speciously presented, might perhaps be entertained as a subject having curious aspects, but on no other ground. In short, if the hand of the idiot is alike badly developed with the brain—if we believe that an arrested development of the fingers, or the presence of supernumerary ones, are signs of degeneration in the race—are we to conclude that perfection of the thoracic limbs is the rule, as has been said, in men of eminence? We need not go so far back as Esop for an example of a great mind in a deformed

body. Condé, Luxembourg, Pope, and other illustrious and celebrated men, were victims of rickets. They had long and knotty hands, one of the most constant signs of this malady. If men of inferior intelligence often have thick and inflexible hands, it is because they are often born under conditions which impose rough work upon them. They receive as a heritage, with the toil of their fathers, this clumsiness of form, which is the consequence of this toil. The hand of the man who is not forced by his position to manual labour is always finer and more delicate than that of the workman, and he transmits to his children this detail of conformation as well as the general resemblance. The delicacy of the limbs, the principal element of their elegance, is therefore a sign of race rather than of intelligence, and belongs especially to the oriental. The hand of a European cannot enter the guard of an Indian sword or poniard. Shall we conclude from that that the Anglo-Saxon or the Norman has less intelligence than the Arab or the Hindoo? De Blainville relates that Récamier attached a certain importance to the form of the hand, and was accustomed to examine those of his pupils with this idea. "Mine," he adds, "were, like the others, submitted to the inspection of the master, and the result was not unfavourable to me." Récamier being present, confirmed the statement of the former pupil of the Hôtel-Dieu, now become an eminent naturalist. But the hand of De Blainville was neither fine nor elegant; it was a well-made, vigorous, and muscular hand, like the body to which it belonged: equally skilful, in fact, in holding a sword, a pencil, or a scalpel.

The wrist-joint, which unites the hand to the fore-arm, resembles in its mechanism that of the shoulder. Eight bones of different and very complicated forms constitute the wrist or *carpus*. Three of these form the articulation with the fore-arm, the others are united to the five bones of the *metacarpus*, the palm, or middle part of the hand, to which the fingers are attached. These are composed of two phalanges in the thumb, three in the index, middle, ring, and little fingers. The first three bones of the carpus are grouped in such a manner as to present an ellipsoid surface on the

side of the fore-arm; a condyle which is received by the elliptic cavity formed by the inferior extremity of the radius and ulna. The hemispheric head of the humerus turns on its axis in the glenoid cavity, but this movement is prevented in the hand by the elongated form of the condyle of the carpus. The rotation of the ulna supplies this want, and the hand turns with the bones which are attached to it in

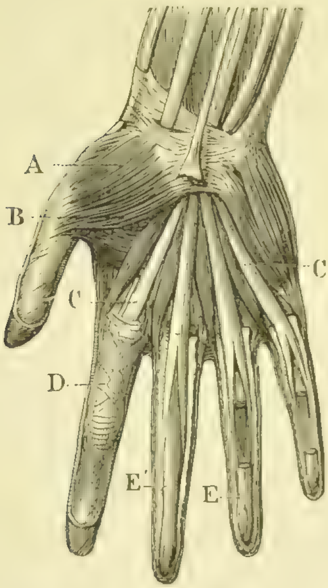


Fig. 15.—The hand, palmar aspect.

A. *Short abductor muscle of the thumb, above and outside of which is seen the opposing muscle (opponens pollicis).*
B. *Short flexor of thumb.*
C C. *Tendons of the superficial flexor of the fingers.*
D. *Sheath of the tendons.*
E E. *Tendons of the deep flexor.*

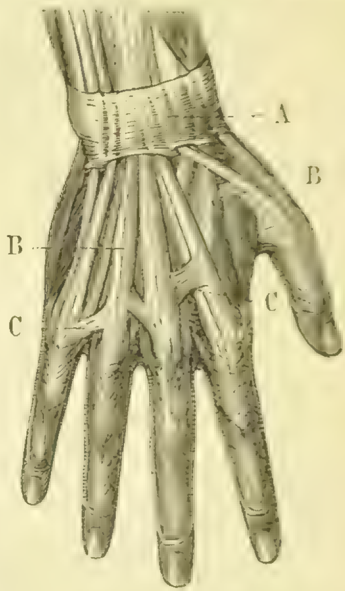


Fig. 16.—The hand, dorsal aspect.

A. *Annular ligament of the wrist.*
B B. *Tendons of the common extensor of the fingers.*
C C. *Tendinous expansions fastening the tendons together.*

supination and pronation. Further, it has a separate movement in flexing the hand forward, backward, or sidewise. In circumduction it describes a cone, and makes many other movements in common or singly.

The numerous muscles which determine these movements form a very complicated mechanism. Their tendons are

interlaced and bound together by bands and aponeurotic fibres, and from this results a more or less complete unity of action. It is sometimes difficult to make a movement with a single finger without the others taking part in it, as in executing instrumental music, for instance; but practice gives to these movements perfect independence. The mechanism of the movements of the hand has been made singularly clear by the recent experiments of M. Duchenne of Boulogne, who has succeeded in distinguishing by means of electricity, the action not only of different orders of muscles, but also of each particular one. Gerdy counts thirty-four distinct movements of the hand, and if we include the combinations of these different movements we shall reach a much higher number. The opposition of the thumb to the other fingers, alone or united, is of all these movements that which especially characterizes the human hand, in which alone it exists in its perfection. This action of the thumb results from its length, from the first metacarpal bone not being placed on the same plane as the other four, as is the case in the monkey, and from the action of a muscle—the long flexor of the thumb—peculiar to the human hand. This muscle completes the action of the other motor of the thumb, and permits man to hold a pen, a graver, or a needle; it gives to his hand the dexterity necessary in the execution of the most delicate work; it is the attribute of his intelligence. In repose the hand of man is presented in an attitude half opposed to the thumb; but it is not so in the monkey, even in the species most resembling man. It is opposable in these animals, but much less so than in man; and the five bones of the metacarpus being on the same plane, the fingers—or toes—can be placed flat upon the ground in walking, in which the four limbs always take part. Properly speaking, then, the hand belongs to man alone, and its conformation does not permit us to consider it as a normal organ of locomotion. It can by turns form itself into a plane, round itself into a cylinder, hollow itself into a gutter, make the fingers spread like so many diverging rays, and form, in the words of De Blainville, a compass with five branches; it collects the fingers in the form of a cone, of a

spheroid, &c.; and lastly, it can reach every portion of the body.

The hand is essentially the organ of touch and of prehension. These functions devolve principally upon its anterior or palmar face. The nervous papillæ with which it is provided abound specially at the ends of the fingers, where they form furrows in elegant curves under the epidermis. The tendons in it are very numerous, and bound together by multiplied connections. Strong aponeuroses and sheaths, through which the tendons slide, make the skin compact, and combine to give unity to the general movements of the different parts of the organ, and independence to partial ones. A layer of adipose tissue, very close in texture, protects, without lessening its power or its delicacy, that network of muscles, vessels, and nerves, this apparatus which sometimes barely touches an object, and sometimes grasps it with such violent pressure. The hand, in fact, is either a delicate pincer or a powerful vice; it guides the burin of the engraver, which leaves behind it the finest trace, the hatchet of the carpenter and the axe of the woodman, whose blows are given with as much strength as skill. The fingers of the sailor knot the heavy cordage, and those of the optician stretch a spider's thread, without breaking it, across the field of an astronomical telescope. The same organ can hold a switch, a club, a sword, a hammer, or a pen. It moulds itself to a body to ascertain its form; it comes to the aid of the eye in completing or rectifying its impressions, and in some cases even supplies its place. Thus the finger of the physician perceives on the surface of an organ the slightest inequality in relief; and the hand of Michael Angelo followed with enthusiasm the contour of the antique torso, which the eyes of the great artist could no longer contemplate.

But nothing gives a more complete idea of the perfection of the mechanism of the hand, than the execution of instrumental music. Examine an artist while he plays on a violin. His fingers rest upon the strings so as to leave them exactly of the length necessary for the tones they are to give. The half of a millimètre, more or less, greatly changes the true-

ness of the note; and a cord a millimètre out of place produces a note which even the unpractised ear recognizes as false. But the fingers fall upon the strings at precisely the point required. They run over them, succeeding each other with giddy rapidity, following every imaginable combination, and yet the hand gliding over the instrument incessantly changes its position. Sometimes a single finger produces an isolated note; sometimes two or three act simultaneously to produce a concord; while a fourth, striking the string with increasing rapidity, produces a trill which rivals that of the nightingale. And even this is not all. The other hand holds the bow, and the movements of the right arm must be in correspondence with those of the left hand; the coincidence between the movements of one hand and that of the other must be mathematically exact. Add to these all the modifications necessary to produce the *piano* and the *forte*, to swell the sound or to let it die away—all, in a word, that constitutes *musical* expression, and it will be admitted that this mechanism is allied to the wonderful, and that it surpasses the most perfect productions of human art.

The agility and flexibility of the hands, the concordance and independence of their movements, is not less remarkable in the playing of the pianist. How is it possible not to admire those two hands, both oftenest occupied together, and the action of which alternates or coincides with so much precision and rapidity; together they produce on an average from six to eight notes at a time—separating, approaching, crossing, and mingling their fingers, which move over the keys as if each one were completely independent of all the others? A skilful pianist produces about 640 notes a minute in medium time, and 960 in extremely quick time. These numbers give us an idea of the rapidity of movement which can be attained by the hand of man.

The devoted servant of the body, the hand which nourishes it knows also how to defend it. It has been said that man is created without arms. What then is the hand which enables him to construct and employ for his defence those ingenious and terrible machines, that hand which can at need itself become a formidable weapon? The poets have sung

the praises of Pollux defending his own life and that of his companions with the arms which nature gave him; but if we admire Pollux battling with the Sicilian giant, we turn our eyes from the arena ensanguined by the gauntlet of Entellus. The soldier considers it an honour to employ with skill in the defence of his country the sword which she has intrusted to him; but he despises the arms and the trade of the gladiator.

The principal function of the upper limb is to remove objects from the body, and to draw them to it; but it can also remove the body from a fixed point, or approach it to one. It is in this way that the sailor raises himself on the rigging, or the gymnast on the trapeze; but the weight of the body is not in proportion to the strength of the limbs which raise it, and although exercise renders this effort less difficult by increasing the power of the muscles, it is evident that here the arm performs a function which does not devolve upon it chiefly, and which belongs to a more powerful member, of which we will now speak.

Lower or abdominal limb.—It is composed, like the upper limb, of four parts—the hip, thigh, leg, and foot. The two bones of the hip, or *pelvic bones*, articulate together and with the *sacrum;* this last, placed between the two like a wedge, transmits by their means the weight of the body to the lower limbs, which are the pillars of the human edifice. On the external face of each pelvic bone we see a deep, hemispherical, articular cavity. This is the *cotyloid cavity*, which receives the head of the thigh-bone, and forms with it the articulation of the hip. The *femur* or thigh-bone is the longest and strongest bone in the skeleton; it is almost cylindrical, and is curved outward, which gives it greater strength. At its upper extremity we see the *head of the femur*, supported by a *neck* which is united to the body of the bone at an obtuse angle. This obliquity has the effect of increasing the distance between the two femurs, and in consequence between the two lower extremities, thus giving to the body a larger base and greater stability. Another result is, that the weight of the body is transferred to the femur, but not directly and in a right line; the necks of the two femurs

form by their union part of an arch upon which rests the upper portion of the cotyloid cavity, and thus divides the force acting upon the lower limbs.

The head of the femur represents nearly two-thirds of a sphere. It exactly fills the cotyloid cavity, but is not itself all inclosed in it, as the depth of the cavity does not exceed half the diameter of the sphere to which it belongs. A very elastic, circular, fibro-cartilaginous ring surrounds the edge of the cotyloid cavity, increasing its size, embracing the head of the femur; and acts as a valve and hermetically closes the articular cavity in which the head of the femur is retained by atmospheric pressure alone. In fact, if we place this articulation, properly prepared, under the receiver of an air-pump, we shall see, as a vacuum is produced, the head of the femur gradually slip down and leave the cotyloid cavity as far as the ligaments will permit, and when air is again admitted into the receiver, it resumes its place in the cavity. This beautiful experiment of E. Weber shows in a striking manner the direct and constant influence of external agents on the functions of the organism.

The inclosing of the head of the femur in the cotyloid cavity gives the articulation of the hip great solidity, which is augmented by the muscles and ligaments which hold the parts together as well as give them motion, so that it is only by the greatest violence that the head of the femur can be forced out of this cavity. This articulation, which is of the same nature as that of the shoulder, permits the movement of the lower limb in every direction, though to a less extent than that of the arm. We shall again have occasion to discuss this movement.

The lower extremity of the femur ends in two oblong, rounded masses, which are called the *condyles* of the femur, which rest in two cavities in the superior portion of the principal bone of the leg, or *tibia*, and form with them the *articulation of the knee*. The *semi-lunar* cartilages, interposed between the two bones, diminish the pressure of the femur on the tibia, and prevent the displacement of the former by increasing the surface and depth of the articular cavity. In front of the knee joint is placed the *patella* or *knee-pan*, the largest

of the sesamoid bones, which adapts itself by two articular facets to those presented by the condyles of the femur, and gives attachment by its upper border to the tendon of the extensors of the leg, while by its lower border it is intimately united to the ligament of the knee-pan, which fastens it to the tibia. In comparing the elbow with the knee, we perceive the striking similarity of the knee-pan to the olecranon. The knee-pan serves as a pulley for the extensor-muscles, the action of which upon the leg is increased by the change of direction given to them, while the olecranon is a powerful lever, by means of which the fore-arm is extended.

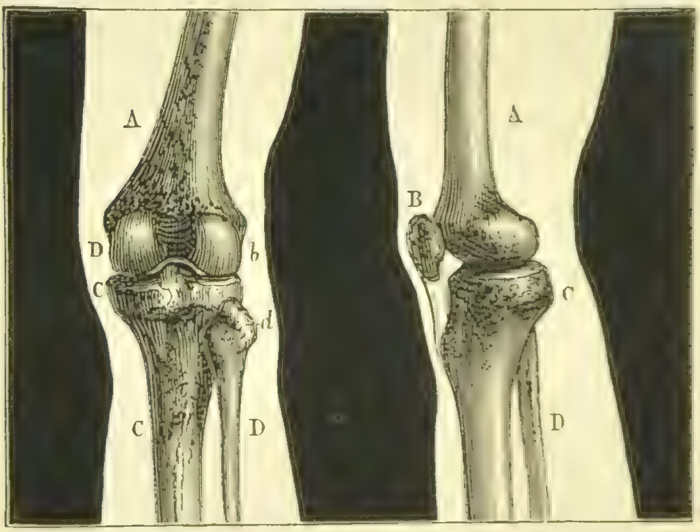


Fig. 17.—Knee-joint.

Front view.
A. *Femur.*
D, *b.* *Condyles of femur.*
d. *Upper extremity of fibula.*
C. *Tibia.*
D. *Fibula.*

Side view.
A. *Femur.*
B. *Knee-pan.*
C. *Tibia.*
D. *Fibula.*

The second bone of the leg is the *fibula*, which is parallel to the tibia, and with it forms the articulation of the foot. This bone, which takes no part in the articulation of the knee, yet represents the ulna, which plays so important a part in the formation of the elbow, while the tibia corre-

sponds to the radius. Nature, by one of those transforma tions of which she furnishes numerous examples, has united the two extremities of the ulna and radius in one, allowing the first of these bones to exist only as a rudiment in its upper portion. This blending of two organs is termed by naturalists a coalescence. The resemblance of the tibia to the radius was remarked by De Blainville, and has been demonstrated by M. Martins in his beautiful work on the pelvic and thoracic limbs.

The lower extremities of the tibia and fibula united form a mortise, in which the *astragalus*, one of the bones of the tarsus, is received, and thus constitute the *tibio-tarsal articulation*, or *articulation of the foot*. The foot moves upon the leg in such a manner as to form with it a straight line when extended. The movement in an opposite direction, or flexion, is much more limited, the two *malleoli* which embrace the astragalus not permitting lateral movements in the foot, those which do take place being made by the articulation of the astragalus with the other parts of the tarsus, though a limited movement of circumduction can be made by the foot.

It has been said that the foot is another hand—*pes altera manus* and if the hand completes the arm, so does the foot complete the leg. Without it locomotion could not be effected except by movements quite different from those of walking, and under conditions of equilibrium much less favourable, and with much greater fatigue; running, and consequently jumping, would be impossible. But if the foot and the hand are varieties of the same type of organization, they present differences in regard to their respective uses; the foot, designed to support the body, is especially remarkable for its solidity; in the hand mobility is the predominating quality.

The foot of man, exclusively designed for the support of the body, is not an organ of prehension, and cannot, like the foot of the monkey, take hold of objects by opposing the thumb to the other fingers; the toes, disposed upon the same plane, have neither the length of the fingers nor the extent and variety of their movements; in a word, it is a foot and not a hand, as it is in the quadrumana.

The foot is composed of twenty-six bones, seven of which constitute the *tarsus*, which articulates with the leg and

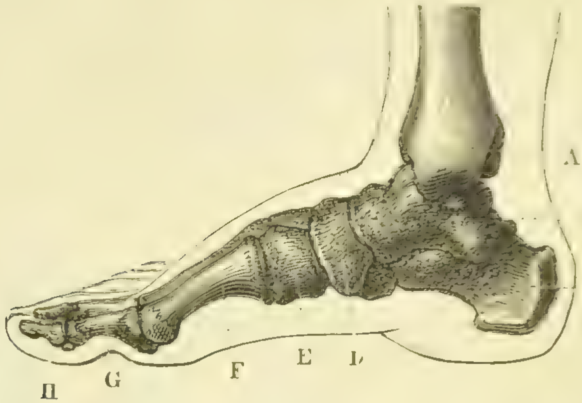


Fig. 18.—Skeleton of the foot.

A. *Internal malleolus, lower extremity of tibia.*
B. *Astragalus.*
C. *Calcaneum.*
D. *Scaphoid.*
E. *Cuboid.*
F. *First metatarsal.*
G, H. *First and second phalanx of the great toe.*

corresponds to the carpus. Five bones form the *metatarsus*, which corresponds to the metacarpus, and articulates with the tarsus behind and with the toes in front. The foot is narrow and thick in its posterior part, thinner and broader anteriorly; it forms a right angle with the leg, and rests upon the ground at the extremities only. The middle portion is in the form of an arch, and in consequence resists shocks and supports pressure much better than it could if it were flat and touched the ground throughout its whole length. And although the parts are very firmly united together, there is sufficient mobility to give great elasticity to the whole, and this elasticity is augmented by the toes. The foot thus supports the weight of the body like an arch and spring combined, giving it in this way great advantage in resistance. And lastly, in jumping from a height it extends itself instinctively, and touches the earth first at its point only, so as to break the shock. This distribution of force, which results from the form and the elasticity of the foot, not only

protects its mechanism, but also avoids the grave injuries which might be produced in certain organs, such as the brain and the liver, by the rebound.



Fig. 19.—The foot.

If we compare the upper and the lower limbs taken as a whole, we shall remark among their principal distinguishing characteristics, that the flexion of the fore-arm upon the arm takes place in a forward direction, while that of the leg is backward. M. Martins has demonstrated that this opposition in their movements, necessitated by their destination to different functions, is due to the twisting of the humerus. The femur is a straight bone and not twisted upon its axis. The humerus, on the contrary, is turned on itself 180°, or half the circumference. This is not the result of the mechanical action of the muscles and of the function of the upper limb; although the form of the bone does not permit this peculiarity to be anatomically recognized till about the second year, it exists virtually as soon as the bone is developed. Muscles, vessels, and nerves all follow this rotating movement indicated by the spiral disposition of the humerus, and most anatomists have pointed it out without hinting at the physiological consequences which M. Martins has shown result from it. This learned observer has shown that the humerus, artificially untwisted, corresponds in all points with the femur of the same side, and by this manœuvre

in an opposite direction to the work of nature, he has explained the proceeding by which she bent the articulation of the elbow forward and that of the knee backward.

The articulations of the lower limb permit to it a great variety and extent of movement. Under the action of powerful muscles it folds back upon itself or becomes a rigid column, raising or lowering with rapidity and facility the body of which it supports the weight. In walking it is carried forward or backward, and by turns extended or bent; it turns on its axis or changes from the vertical in order to maintain the equilibrium by the direction of the foot or to enlarge the base of support. It can raise itself laterally almost to a right angle with the body, and in front it approaches it still more nearly. In fencing it bends or is extended, raises and lowers the body, and carries it backward and forward by movements which succeed each other almost as rapidly as those of the arms. But it is especially in the varying steps of a skilful dancer that we can admire the perfection of this mechanism, and all the suppleness, strength, and agility that exercise can give to it.

CHAPTER V.

Motion. –Effort. –Locomotion; standing, walking, running, jumping, swimming.

Motion.—Physiologists remark several varieties of motion which may be grouped in two—voluntary and involuntary movements. Among the *involuntary movements*, which are also called automatic, some result from the impression produced by an idea, a passion, or a scene, gay or sad, or by a movement identical with that which is produced. Such are laughing, and the motions of the face expressing sadness, anger, fear, and other moral or physical impressions; trembling of the limbs in consequence of deep emotion, yawning, and so forth. Others proceed from the excitement of the sensitive nerves, such as sneezing, coughing, winking, chattering of the teeth, or shivering after a cold bath.

In certain cases, in fact, impressions transmitted from the organs to the brain, either directly by the nerves of sensation or indirectly by the spinal cord, without any sensation taking place, or what amounts to the same thing, without our being conscious of any, occasion an excitement which is transmitted to the motor-nerves, and causes movements in which the will has no part. These movements are generally executed by the muscles of organic life, which are not under the control of the will; but they can also be made by those which are under its control. These are called *reflex* movements. Some of them are undoubtedly automatic; as for the others, it has not been demonstrated that a sensation and an act of the will do not precede the muscular contraction. Thus sneezing and coughing are independent of the

will, it can neither prevent them nor arrest their development. It is the same with the chattering of the teeth, with shivering and winking of the eyelids on contact with the air, with the tears, or only when a foreign body menaces the eye. In this last case, although the muscular contraction is instantaneous and seems to be involuntary, it is evidently preceded by a sensation which the eye has transmitted to the brain. This may even be considered as voluntary, since if the attention is excited; the will can oppose the instinctive movement.

Other movements take place in the organism of which we have more or less perception; when a carriage threatens to overset, for example, we throw ourselves to the side opposite the inclination; or when suddenly coming on the edge of a precipice the body stiffens or is thrown backward; and when a player at ball or billiards inclines or turns in the same direction in which he wishes to direct his ball. Analogous phenomena are caused by a sort of attraction or instinctive imitation. When, for example, the eyes follow the movement of a great waterfall into a gulf, the body very soon follows the oscillations, though we do not perceive them until the motion becomes so great as to threaten to drag us into the abyss. We are indebted to M. Chevreul for the observation and explanation of effects of this nature, of which charlatanism avails itself in table-turning. If the elbow be placed upon a table, and a pendulum formed of a string and a ring be held in the hand, and we fix the eyes on the ring, we shall soon see it begin to oscillate, although the arm apparently remains immovable; the oscillations may keep the same direction, or change according to the mental desire, and this without any bad faith or a consenting movement on the part of the person holding the pendulum. But if we place a support under the hand near the end of the fingers, or a bandage over the eyes of the experimenter, the oscillations cease. They were caused by an almost imperceptible and involuntary movement of the fore-arm and hand, under the influence of the eyes looking at the ring and the direction that it takes. And again it is a similar movement or series of movements which gives the impulse to the turning

table; in the unconsciousness of the muscular contraction lies all the merit of this phenomenon, which loses its marvellous character as soon as you show the too credulous performers that they themselves are the involuntary movers.

Voluntary movements, as their name indicates, are produced under the influence of the will, but not under its direct or immediate action. The volition of the movements of locomotion, for example, emanate from a certain part of the brain, from the cerebral lobes; but in order that the movement may be executed, the muscles must contract, and this muscular contraction owes its origin to a force which emanates from the occipital protuberance, a different part of the brain from that which gives birth to thought. Observations on paralytics prove that the will is insufficient to produce movement.

In order that movements may be executed in the order and with the unity necessary to the accomplishment of the will, they must be co-ordinate. Several physiologists, and especially Flourens, have regarded the cerebellum as the organ essential to this co-ordination of movement. A lesion of this part of the brain produces a disturbance in locomotion similar to that caused by drunkenness; but pathological observation has demonstrated that there is sometimes absence of co-ordination when the cerebellum is not affected.

The muscles unite in the voluntary movements, some as motors, and others, antagonistic to these, as the moderators of movement. M. Duchenne (of Boulogne) has shown that in the voluntary movements of the limbs and the trunk these two systems of muscles, *impulsive* and *modifying*, are simultaneously contracted by a double nervous excitation; one to produce the movement and the other to modify it. Without this unity of intention between the antagonistic muscles, the movements would lose their precision and their certainty.

Effort. When one or several groups of muscles contract themselves strongly in order to perform a function requiring force, or to overcome an obstacle, to draw or push away a body, the name *effort* has been given to this action of the muscles. There is effort in walking, climbing, running, and a great number of other functions. Whatever muscles take

part in effort they must have a point of support or fulcrum, directly or indirectly upon the skeleton of the trunk, that is on the spinal column and the bones of the thorax. An effort is always preceded by an inspiration which dilates the thorax, thus rendering the bones of which it is composed immovable by the contraction of the inspiratory muscles, and furnishing a fixed point to the muscles attached to these bones. Thus, one after another, the greater part of the muscles of the system joins in a movement of which sometimes the arm or the hand only is the immediate instrument. The proof of this is the impossibility of making a movement distinct from that which is the immediate object of the effort, without this effort ceasing or diminishing. When it is at its highest point, respiration is suspended, the glottis closes or remains slightly open, according to the nature and the degree of intensity in the effort; the inspired air distends the lungs, and if a part escapes it is too small to lessen the expansion of the chest; the abdominal viscera are compressed from above by the diaphragm in front, and laterally by the muscles of the abdomen. During certain efforts the air is expelled slowly through the glottis, and when the movement terminates suddenly with redoubled force, the expiration is accomplished rapidly and sometimes in the form of a cry. The sailor who hauls in a rope, or the baker as he with difficulty raises the dough to throw it back into the kneading-trough, accompanies the movements which he executes with a cry of which the rhythm expresses the different periods of the effort.

Locomotion.—Man moves over the surface of the ground by three principal methods of progression—walking, running, and leaping; but the point of departure is always the vertical position. In this attitude, which characterizes the human race, the equilibrium of the head upon the vertebral column, and that of the trunk upon the coxo-femoral articulations, and of the thighs on the legs, is independent of all muscular contraction, the ligaments being sufficient to insure it. And farther, the muscles of the neck, of the trunk, and of the thigh maintain the rigidity of the spinal column, oppose or prevent the flexion of the knee, and restore the equilibrium when it is compromised, while the muscles of the leg prevent

the flexion, anterior or posterior, of the tibio-tarsal articulation, the surfaces and ligaments of which only permit an unstable equilibrium of the body upon the feet. Lastly, the feet, separated from each other by a distance equal to that



Fig. 20.—The leg in standing.

The foot resting the toes on the ground. The foot resting flat on the ground.

which divides the heads of the femurs, complete the mechanism by which man alone, among all living beings, stands erect with his face placed vertically, and on a plane parallel to that of the body, but not turned toward heaven, as has been poetically said.

In the attitude of a soldier without arms, with the heels touching each other, and the feet forming nearly a right angle, a stronger contraction of the muscles of the leg is

necessary, and consequently fatigue is sooner induced. When resting on one foot only the body departs laterally from the vertical and leans a little backward, the leg which supports only its own weight rests on the ground, with the muscles completely relaxed, acting as a support and counterpoise. This attitude when standing is the least fatiguing, firmest, and also the most elegant; it is the one preferred by painters and sculptors, and was considered by Leonardo de Vinci as the most natural.

When the body moves it is divided into two quite distinct sections: the one, comprising the head, trunk, and upper limbs, representing the mass to be transported; the lower limbs are at once the movable supports of the superior parts of the body, and the agents of propulsion which communicate to them the movement of translation. In all movements of this nature the trunk inclines forward at an angle which varies according to the quickness, from 5° 7′ in the slowest walk to 22° 5′ in the fastest running. From this position there is a constant tendency to fall forward, which is neutralized by the moving of the lower limbs in such a direction as that the heads of the femurs shall always serve as the point of support for the body. M. Longet compares this unstable equilibrium of the body upon the femurs to that of a rod on the end of a finger, so inclined that the only means to prevent its fall is to carry the finger forward in the same direction as the inclination, more rapidly as this inclination becomes greater.

By their alternate flexion and extension the lower extremities give an impulsion to the trunk, they lengthen and contract in a direction inclined to the horizon, since it is forward and not vertically that they push the body; the result is that the centre of gravity sinks toward the ground just in proportion to the rapidity of the mode of progression.

Each extremity props itself by turns on the ground, and then the impulse being given the knee bends, the heel rises, the foot is lifted, the limb, shortened by flexion and suspended from the pelvis, is directed from behind forward, and is again placed upon the ground.

In this movement the leg, according to the brothers

Weber, represents a pendulum which bends and oscillates by its weight alone; according to M. Duchenne (of Boulogne), it obeys the contraction of the flexor-muscles.

The experiments of the Webers having demonstrated, as stated above, that the head of the femur is retained in the cotyloid cavity by atmospheric pressure alone, these skilful observers conclude that in the second movement in walking the weight of the thigh alone determines the flexion of the joints and the oscillation of the three segments of the pendulum, which is then represented by the lower extremity. Basing his opinion on pathological observation, M. Duchenne thinks that the contraction of the flexors of the thigh, leg, and foot is the real cause of the second movement of the extremity in walking, and that the action of weight contributes very little to it. According to M. Béclard, the tonicity of the flexor-muscles, developed by extension, suffices for seconding the pendulum movement of the lower limb.

In *walking* the body advances without ceasing to rest upon the ground, and by effecting a succession of movements, which are divided in each step into two principal ones. First,—the body rests upon the two lower limbs; the right leg, placed behind and inclined to the horizon, touches the ground at the extremity of the metatarsus and at the toes, it stretches out, and the foot is raised to an angle of forty-five degrees; now the left limb is placed forward, resting on the ground on its sole, the knee is a little bent, the heel exactly under the head of the femur, and the trunk slightly inclined forward. Secondly,—the left leg alone supports the weight of the body; it lengthens by extending the knee and straightening the foot; its direction inclines to the horizon, and the body pushes itself forward, while the right leg is raised from the ground by bending the knee, follows the movement of translation given to the body, executes half an oscillation, and touches the ground, first at the heel, which places itself exactly under the head of the femur, and then on the sole of the foot on which the body rests.

To accelerate his movement man inclines more forward, the centre of gravity falls nearer to the earth, and the flexion of the limb placed behind is greater, the pendulum is shorter

and its oscillation more rapid; at the same time the greater flexion gives more force to the extension, and the impulsion forward is increased; and more still, extension acts in a direction still more inclined, which results in a lengthening of the step. The motion is also increased by the extension of the leg resting on the ground while the other oscillates, in such a way that when the latter touches the ground the former detaches itself in order to swing in its turn. In walking quickly the body rests upon the ground only by one foot at a time.

When walking, and especially when walking rapidly, the arms accompany with their isochronous oscillations the movements of the lower limbs, and contribute to maintain the equilibrium: indeed it is next to impossible to walk quickly when the arms, from any cause whatever, cannot oscillate.

According to the experiments of the brothers Weber, the speed of a man of ordinary stature is, in rapid walking, about 10,267 yards per hour. This speed could not long be maintained, and must be considered as exceptional. In ordinary walking the speed is nearly four miles an hour, and can be kept up for a long period. But exercise and a special aptitude for it enable some men to walk great distances in a relatively short space of time. Trained walkers have gone seventy five miles in twenty hours, and walked the distance of thirty-seven miles at the rate of five miles an hour. The mountaineers of the Alps are generally good walkers, and some of them are not less remarkable for endurance than for speed. Jacques Balmat, who was the first to reach the summit of Mont Blanc, at sixteen years of age could walk from the hamlet of the Pélerins to the mountain of La Côte in two hours—a distance which the best trained travellers required from five to six hours to get over. At the time of his last attempt to reach the top of Mont Blanc, this same guide, then twenty years old, passed six days and four nights without sleeping or reposing a single moment. One of his sons, Edward Balmat, left Paris to join his regiment at Genoa; he reached Chamonix the fifth day at evening, having walked 340 miles. After resting two days he set off again for Genoa, where he arrived in two days.

Several years afterward this same man left the baths at Louèche at two o'clock in the morning, and reached Chamonix at nine in the evening, having walked a distance equal to about seventy-five miles in nineteen hours. In 1844 an old guide of De Saussure, eighty years old, left the hamlet of Prats in the valley of Chamonix in the afternoon, and reached the Grands Mulets at ten in the evening, then after resting some hours he climbed the glacier to the vicinity of the Grand Plateau, which has an altitude of about 13,000 feet, and then returned without stopping to his village.

We will cite in addition the performance of a man from Thun, who walked in September, 1867, a distance estimated at forty Swiss leagues in twenty-three hours, representing at least thirty-four hours of walking for ordinary travellers.

Running differs from walking principally in the fact that at a given moment the body leaves the ground, and passes through space in the same manner as a projectile. The body is inclined more forward, and the centre of gravity is lower than when walking. The lower limbs execute the same alternate movements as in the first mode of progression; but at the moment when the right leg leaves the ground and commences its demi-oscillation, the left, which is bent and only touches the ground at the extremity of the foot, pushes rapidly forward, and with sufficient force to throw the body upward and forward, and the two legs oscillate together during an instant, then the one which left the ground first falls before the other on the point of the toes. The body has made a spring, and the same manœuvre takes place alternately on each side, and the result is a succession of springs which constitute running.

Trotting is running when the impulsion forward is not so strong, and the movements are less rapid, which renders it more applicable to uneven ground, where it is necessary to choose the place where the foot is to be placed at each step.

The greatest attainable speed for a man is, according to the brothers Weber, seventeen miles in an hour; but if this speed has ever been maintained for one hour, which is doubtful, it could not certainly be continued much longer. The maximum of speed attained in the gymnasium of

Amoros was twenty-five miles in two hours and forty-five minutes, that is, about nine miles an hour.

Leaping is, properly speaking, nothing but a step of running taken singly. A man can jump with his feet joined, that is to say, the two feet quit the ground at the same instant, and the body is thrown vertically upward and forward, or backward. The jump may be preceded by running several steps in order to get under way, as it is termed. In this case the speed acquired during the first steps is added to the impulse given to the body by the last one. By exercise men have succeeded in jumping vertically a height of two mètres, and horizontally over a space of five or six mètres. Amoros speaks of an Englishman who jumped across a ditch ten mètres in width.

Swimming.—Man can sustain himself upon the water, and traverse it for a considerable space by swimming; but this is not an instinctive method of locomotion for him—he must *learn* to swim, while walking and the other modes of progression are natural to him, and are not acquired by study. Man walks, runs, and jumps just as an amphibious animal swims without having learned to do so; but to swim he must study the attitudes and the movements which neutralize the effect of his specific gravity, which prevent him from sinking into the water, and permit him to gain a resting-point in order to displace it.

The quadruped swims as if walking in the water, that is, by making just the same movements as in walking on the ground. Man can, it is true, swim as animals walk, striking the water with his four members; but he is soon overcome by fatigue, and to swim for any length of time he must execute other movements considerably complicated in their combinations. It is from that modest amphibian, the frog, from which he borrows in this case the method of progression, and this loan is certainly the most inoffensive of all those which he makes from the animals. Although he seems to turn his members quite away from their normal functions, he soon attains the power of prolonging this exercise, which is eminently healthful and very precious, since he finds in it a means of saving his own life and the lives of his fellowmen.

CHAPTER VI.

The head.—The skull, bones of the skull, sutures, arch of the skull, base of the skull.—Measurement of the skull; facial angle, angle of Daubenton; comparison of the superficies of the skull and of the face.—System of Gall.—The face, bones of the face, upper jaw, lower jaw.

The Head.—The head is the most important part of the body, and to it and to the organs which it contains our attention is most particularly attracted. The heart and lungs support life by the respiration and the circulation, the digestive apparatus nourishes the body, but the head is the seat of intelligence, the centre in which all the nervous impressions meet and from which radiates the will. In the head are united the organs of sight, of hearing, of smell, and of taste; the face, almost entirely formed by the grouping of these organs, expresses by the aid of numerous muscles the impressions transmitted to the brain, the passions, calmness or agitation of mind, and, within certain limits, the phases of thought. In other regions of the body life is unconscious, and the functions in their performance, whether healthy or diseased, are executed mechanically; the head alone perceives sensations and interprets their meaning, it is by it that man knows himself, by it he feels that he lives, and is able to say, "I think, therefore I am."

The head is formed of two distinct parts: first, the skull, a bony case which envelops the brain, and incloses in the thickness of one of the bones of which it is formed the organ of hearing; secondly, the face, in which are united the organs of sight, of smell, and of taste.

The skull is composed of eight bones: the *frontal* or coronal, which corresponds to the forehead or *sinciput;* the

occipital in the posterior part of the skull or *occiput;* the two *parietal* bones, which form the side walls of the skull, and contribute, with the frontal and occipital, to form its arch; the two *temporal* bones occupy, as their name shows, the region of the temples; the *ethmoid*, which owes its name to the sieve-like plate of its upper surface; and the *sphenoid*, so called because it is wedged in between all the other bones with which it articulates, and which rest upon it as upon the keystone of an inverted arch, thus forming the base of the skull on which the brain rests. The frontal, occipital, parietal, and temporal bones are flat, formed of two plates of ivory tissue—*internal* and *external tables*—between which is a more or less thick layer of spongy tissue.

The bones of the cranium are united by means of *sutures* formed by the junction of the teeth of their serrated borders, almost precisely like what is termed in architecture dove-tailing. At birth the bones which form the arch of the skull are united only by a membranous tissue, and their borders overlap each other even on slight pressure in such a way as to lessen the diameter of the head; but although the sutures are not yet developed, a part of the tooth-like processes already exists in a rudimentary state. The membranous intervals are greater at the point of union of the occipital and frontal with the parietal bones; these spaces are called the *fontanelles.* They are soon filled with bony tissue, and at four years of age not a trace of them remains. About the end of the third year the borders of the bones are cut into fine notches or teeth, which increase in number till the period of adolescence. Before this the suture which unites the two halves of the frontal bone begins to disappear; and later still, when the brain is fully developed, the other bones gradually close together.

The internal surface of the skull presents a series of depressions, portions of the arch which have been called *fossæ*, and according to the bones which constitute them, the *frontal*, *occipital*, and *temporal fossæ*, and which correspond to the projections which we see on the external surface. There are also a great number of projections and depressions, which to a certain extent are modelled to the surface of the

brain, but which form no relief on the outside of the skull. There is no opening in the arch of the skull, but there are several in its base through which the nerves and blood-vessels pass; the most important of these is the *foramen magnum*, which is the communication between the cavity of the skull and the vertebral canal.

The skull is oval in form flattened at the base, with the larger end at the back. It is never perfectly symmetrical, and differs in shape and size according to age, the individual, and the race. It is larger in proportion in the infant than in the man, and in the white race than in the other races. But whatever may be the varieties which it presents, they appear exclusively in the arch.

Starting from the principle that the skull is modelled upon the brain, in measuring its dimensions we seek to ascertain that of the organ which it incloses. To attain this object, Camper drew two straight lines, the one starting from the first incisors of the upper jaw and passing over the median line of the forehead; the other starting from the auditory canal and carried horizontally till it encountered the first, formed with it an angle called the *facial angle*, which is from 80 to 85 degrees in the European, 75 in the Mongolian race, and 70 in the Negro. This anatomical character, considered as an expression of intelligence, did not escape the notice of the artists of antiquity. The statues which they have bequeathed to us prove this: among their gods, the facial angle of Jupiter Trophonius, for example, is 90 degrees.

Daubenton proposed to measure the occipital angle to complete the measurement of Camper, which applied only to the anterior portion of the skull; but these angular measurements would not give the extent of a solid nor of a cavity; the thickness of the bones at certain points, and the varying development of the cavities or *sinuses* comprised between the internal and external tables, would take from these measurements much of their signification. In order to be more exact, Cuvier, dividing the head by a section from front to back, compared the area of the skull with that of the face, leaving out the lower jaw: he found that in Europeans, the area of the skull was four times that of the face, and in

the Negro the area of the face is greater by a fifth, that of the skull being proportionally less.

This last method of measurement, even though it gives an idea of the relative intelligence within narrow limits only, is at least founded upon certain facts, and it expresses the law of the proportional development of the face and skull in the superior animals. And even in measuring by the facial angle the causes of error may be avoided to a certain extent, and this measurement is an expression of an incontestable anatomical fact.

But this is not the case with a doctrine which was received with enthusiasm about the beginning of this century, though now almost forgotten. We speak of phrenology. Gall professed to discover the degree of development of the faculties by exploring the cranium. According to his theory, the skull is moulded upon the brain, and presents protuberances corresponding to those of that organ, and thus gives the measure of the development of the intellectual and emotional faculties. These faculties, which he localized in the encephalon, were composed, according to him, of a series of conoid bundles, the base of which corresponded to the surface of the brain and the apex to the *medulla oblongata*. Each one of these cones was the seat of a faculty, of which he numbered twenty-seven, placing all the intellectual faculties in the anterior portion of the brain, the animal faculties in the posterior portion, and the moral faculties in the middle portion over the ear: the first confined for the most part to a very small space, and the others distributed over larger surfaces. The pupils of Gall added eleven faculties to those which he had classed. Among the latter, the sense of right and wrong—or as they termed it, conscientiousness—did not appear.

To this system it was objected that if the principal projections of the exterior of the skull, the frontal and parietal protuberances, for example, correspond to the depressions or fossæ of the interior, no external relief indicated the digital impressions and the small cavities which correspond to the surface of the brain; that at several points an external projection corresponded to one on the inner surface: that

the arch of the brow (the superciliary ridge), where six faculties are located, is more or less prominent, not from the cerebral relief, but from the development of the frontal sinuses; and that there is no resemblance between the form of the internal table and the external table in the frontal region. Gall was therefore wrong in tracing upon the brain the seat of each faculty according to the elevations which he found upon the skull. It was added also, that, even admitting the localization of the faculties and the divisions of the brain, it was very irrational to unite all the faculties in corresponding portions of the cranial arch, and to attribute none at all to those portions of the brain which are not in contact with the skull, or which rest laterally and in front on its base. This exclusive grouping was unjustifiable, and is to be considered as purely arbitrary.

Gall and his school invoked the aid of the comparative anatomy of the brain in support of his system. Leuret gave them a death-blow by showing that the study of the brain in the animal scale proves the facts to be in entire disagreement with the theory of the German savant, and that it disproves at all points the propositions of phrenology.

The *face* is composed of fourteen bones, which form, by their union with each other and with the bones of the skull, the cavities in which the organs of sight, of smell, and of taste are placed. Twelve of these bones are in pairs, and placed symmetrically on each side: these are the superior maxillary, the malar or cheek bones, the nasal bones, the lachrymal bones, the superior turbinated bones, and the palatine bones. Two are not paired: these are the vomer and the inferior maxillary. The superior maxillaries, with the lachrymal and malar bones, combine to form the inferior portion of the orbit; they are united to the temporal bones by the malar bones, the protuberances of which form the cheek-bones. At their alveolar border the teeth are placed, and the space included in the dental arch is called the palatine arch, which is prolonged backward by the palatine bones. The nasal bones form the upper portion or root of the nose; below these, and between the superior maxillaries, is the nasal cavity, which is divided into two parts by a partition,

of which the vomer forms a portion. The superior turbinated bones articulate with the maxillaries and contribute to multiply the nasal sinuses, in which are the ramifications of the olfactory nerves.

The *inferior maxillary* is at first composed of two bones, which are early joined together at the point called the *symphysis of the chin.* The branches of this bone form a right angle with its body, called *the angle of the jaw*, and at their superior extremity they divide into two apophyses; namely, the *condyle*, which articulates with the glenoid cavity of the temporal bone, and the *coronoid* process, where the tendon of the temporal muscle is inserted. This is one of the muscles which draw the lower jaw to the upper one in chewing the food.

This skeleton, with its strange and imperfect outlines, this type of Death, disappears under the muscles and teguments, which cover it with an elegant envelope. The eyelids veil the orbit and protect the eye, the watchful sentinel and investigator of the exernal world, the admirable instrument which enables the brain to contemplate the works of creation and to express its most vivid impressions. The nose covers the organs of smell, while it completes them by protecting their sensibility; the lips are placed before the mouth, and they are at once an organ of prehension, a docile and indefatigable guard, a necessary instrument in articulating sounds, and one of the most expressive of the features which combine to form the physiognomy. The *concha*, or external ear, surrounds the auditory canal, and serves to collect the sonorous waves, and to give expression to the head. The hair, the eyebrows, and eyelashes protect the skull and the eye against external objects, and at the same time their different shades, and curves, and undulations, greatly contribute to the beauty of the whole. Lastly, the skin of the face is animated with the most delicate tints, or is clothed in the vigorous tones and that admirable carnation which has been so well rendered by the Venetian painters.

CHAPTER VII.

Digestion.—Waste of the organism repaired by alimentation.—Hunger.—Thirst.—Organs of digestion; abdominal cavity, peritoneum.—Digestive apparatus.—Mouth, lips, cheeks, teeth, palate, soft palate, tongue.—Pharynx.—Œsophagus.—Stomach.—Intestinal canal; small intestine, large intestine, intestinal convolutions, mesentery, omentum.—Mucous membrane.—Liver.—Pancreas.—Spleen.—Kidneys.—Mechanism of digestion.—Digestion of the stomach, gastric juice, peristaltic movement, chyme.—Intestinal digestion, bile, pancreatic juice, chyle.—Absorption; endosmosis, exosmosis, functions of the veins and lymphatic vessels in absorption, rapidity of absorption.

Digestion.—The human body loses every day through various channels, by exhalation or excretion, about 310 grains of nitrogen, an essential principle of animal matter, and 6½ lbs. of water, and burns 10½ ounces of carbon in contact with the oxygen of the atmosphere. A very short time, therefore, is sufficient to exhaust the organism if it does not find in the alimentation the new elements by which it is reconstructed. Of this unceasing necessity of repairing the loss which the organs sustain by the action of life, man is imperiously reminded by hunger and thirst; hard conditions of existence. He can support the first of these wants for a time, which varies according to age and individual strength; it is a sensation agreeable at first, but it soon becomes a torture, a succession of atrocious pains, and moral and physical destruction follow. The annals of hunger are terrible in science and in history; it has been called, with too much reason, an evil counsellor, and he who has the means to appease it each day should be thereby reminded of those less fortunate than himself.

Thirst is a sensation painful from the first, and can be borne for a shorter time than hunger; for it necessarily implies the privation of all liquid aliment, and exhaustion supervenes much sooner than when a man is deprived of solid food, but is able by the aid of a little water to prolong his life for some days.

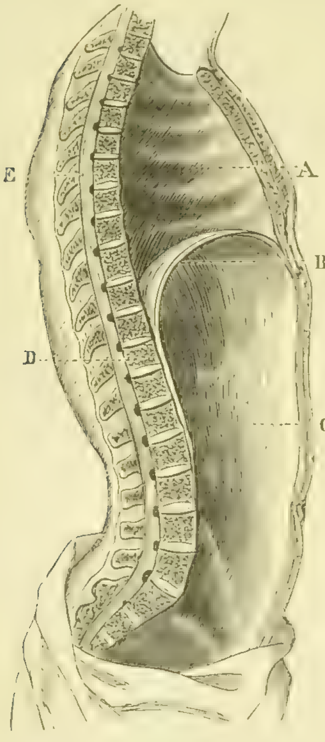


Fig. 21.—Section of the trunk and its cavities in the median line.

A. *Cavity of the chest.*
B. *Diaphragm.*
C. *Abdominal cavity.*
D. *Vertebral column.*
E. *Spinal canal.*

The organs of digestion, of which we will give a summary idea, are, for the most part, contained in the abdomen.

Abdominal cavity.—This cavity is the largest in the body; it is situated below the chest, from which it is separated by the diaphragm, and extends to the lower extremity of the trunk. It is divided into several parts or regions, which are—1st. In the upper portion, the *epigastrium*, corresponding to what is called the pit of the stomach, and the two *hypochonders* (*hypo*, under; *chondros*, cartilage), which rise up from each side of the epigastrium, under the double arch of the diaphragm and under the cartilages of the ribs. 2d. In the middle, the *umbilical* region, and the *flanks* or sides. 3d. In the lower portion, the *hypogastrium* or lower belly, and the *iliac fossæ*, inclosed by the bones of the same name. The walls of the abdomen are formed principally by muscles and aponeuroses, combined with the vertebral column and the bones of the pelvis. The lower or false ribs have only an indirect connection with the abdominal cavity, resulting from its being set into the bottom of the chest.

The abdominal cavity is lined with a serous membrane called the *peritoneum*. Like all the membranes of this nature, it is formed of cellular or laminated tissue and elastic fibres; its free surface is covered with an *epithelium*, a sort of epidermis, which resists the continual friction resulting from the movements of the organs; and lastly, like all its congeners, it is a sac without an opening, folded on itself, and consequently with double walls. The space between these walls is empty, their corresponding surfaces rub freely against each other, and are moistened by a fluid analogous to the serum of the blood, a secretion peculiar to these membranes, and from which they derive their name. The internal wall of the sac covers all the organs which it contains, and the external wall is attached throughout its whole extent to the cavity which it lines. We shall, by-and-by, have occasion to return to the disposition of the peritoneum.

The *digestive apparatus* is one of the most complex and extensive in the organism; it is accessible to our investigations in all its parts, and we are able to follow the working of the functions which devolve upon it. We can observe the metamorphosis which the food undergoes; we can reproduce in our laboratories a part of these transformations; a step farther, and, as Fontenelle has said, we should surprise nature in the very act; but this impossible step is the immense distance which separates inert matter from organized substance, physical and chemical phenomena from the vital functions.

The *organs of digestion* are the mouth, the pharynx, the œsophagus, the stomach, the liver, and the pancreas. The spleen and kidneys are appendages of the digestive apparatus, but belong rather to the circulatory or excretory.

The *mouth* forms the entrance to the digestive apparatus; it contains the organ of taste, and serves in eating and in articulating sounds. Bounded above by the palatine arch, below by a muscular wall and by the tongue, on the sides and in front by the cheeks and the lips, the mouth presents in front the opening of the lips, behind, the isthmus of the throat by which it communicates with the pharynx and over which the soft palate falls.

The *lips* form the anterior wall of the mouth, and are composed principally of the *orbicular* muscle of the lips, to whose

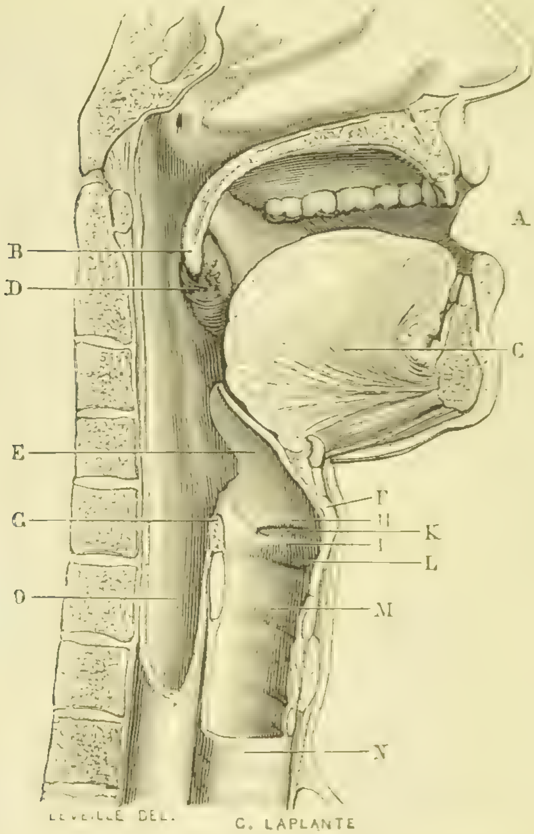


Fig. 22.—Section in the median line through the inferior portion of the nasal fossæ, the mouth, pharynx, larynx, œsophagus, and trachea.

A. *Mouth.*
B. *Soft palate.*
C. *Tongue.*
D. *Tonsil.*
E. *Epiglottis.*
F. *Thyroid cartilage.*
G. *Arytenoid cartilage.*
H. *Superior vocal chord.*
I. *Inferior vocal chord.*
K. *Ventricle of the larynx.*
L. *Larynx.*
M. N. Trachea or windpipe.
O. Pharynx, before which is seen the cricoid cartilage.

concentric fibres are attached nearly all the muscles of the face; a very thick skin intimately united with the orbicular

muscle, a layer of small salivary glands subjacent to it, and the mucous membrane, complete these two movable, extensible, and contractile veils. The lips are an organ of prehension and suction; they prevent, especially the under lip, the escape of saliva; they assist in the articulation of sounds and in playing upon wind-instruments; and lastly, they take an extensive part in the expression of the physiognomy. Abundantly provided with nerves and vessels, the lips are extremely sensitive, especially on their borders, where the skin grows thin, takes a carnation tint, and is insensibly transformed into mucous membrane. Although the orbicular muscle limits them in a measure, and imposes upon them certain functions and a distinct region, they are in reality only the anterior portion of the cheeks, with which they are in constant communication by movement and function.

The *cheeks* form the sides of the face and the lateral walls of the mouth. They embody in their substance the muscles intrusted with the performance of the complex functions of the mouth. One of these muscles, peculiar to that part of the cheek which forms the buccal wall, brings the food between the jaws and reacts against the distension of the cheeks by the air. Its action in playing on wind-instruments has given it the name of *buccinator;* it contributes also to the expression by drawing the commissure of the lips backward, while the great and small *zygomatic* muscles raise it. The *triangular* muscle of the lips, on the contrary, lets it fall; and lastly, the *masseter*, a thick muscle of great power, brings the lower jaw against the upper one, and with the *temporal* muscle performs mastication. The internal face of the cheeks is covered with mucous membrane, and its whole surface is scattered over with little openings, which give passage to the saliva, which is secreted by a great number of glandules analogous to those in the lips. Near the middle is the opening of the *canal of Sténon*, through which the saliva secreted by the *parotid gland* is poured into the mouth. This gland is situated, as its name indicates, in front of the ear, and is the most important of the salivary glands.

The *teeth* are implanted in the alveolar border of the upper and lower jaw, forming two symmetrical arcades, and when the

mouth is closed they circumscribe its limits like an internal wall. They are twenty in number in the child, and thirty-two in the adult. They are divided into eight *incisors*, four *canines*, and twenty *molars*. The last four molars are called the "wisdom teeth." A tooth is composed of three distinct parts: the pulp, the ivory, and the enamel. Vessels and nerves penetrate the *pulp*, but do not go beyond; the *ivory* which envelopes the pulp constitutes the root and the crown of the teeth. That part of the tooth where the crown joins the root is called the *neck*. This last is covered with a layer of bony tissue. The *crown* commences at the neck, and is overlaid with the enamel, a tissue very poor in animal substances, and almost inorganic. The teeth are not bones; though their roots have an osseous covering, they do not present either in their essential parts—the ivory and the enamel—or in their mode of development and their physiological conditions, any connection with the osseous system; they are considered as analogous to the epidermic productions, the hair, nails, &c., which they resemble in many respects.

Palate.—The palatine arch is formed, as we have already seen, by the upper jaw-bones and the palatine bones. It is circumscribed in front and on the sides by the upper teeth. It is covered with a thick mucous membrane, very hard, and presenting transverse ridges. Behind, it is continued by a musculo-membranous partition, called the *veil of the palate*—the *soft* palate—covered anteriorly by the mucous buccal, posteriorly by the pituitary membrane. Its inferior border is free and floating, presenting on the median line an appendage called the *uvula*. Each of its lateral borders forms a continuation with the tongue and the pharynx by two folds, which are called the *pillars* of the soft palate, and between which on either side lie the tonsils. In a state of repose the soft palate closes the back part of the mouth; but when raised prevents the food and drink, and the voice also, from passing into the nasal fossæ.

The *tongue* is a fleshy body, symmetrical, longer than it is broad, flattened from above downwards, thicker toward the middle than at its extremities, larger behind than in front, and rounded on the edges. The posterior extremity of the

tongue is called its *root*, and the anterior the *point* or tip. Its upper surface or *back*, and a part of its edges, are covered over with *papillæ*, which are divided into conical, fungiform, and cup-shaped papillæ. Its lower surface is free for about one-third of its length anteriorly: at the point of attachment we observe a mucous fold called the *frænum linguæ* or bridle of the tongue. Its two posterior thirds receive the muscles which fasten it to the neighbouring parts. The base or *root* of the tongue is fixed to the hyoid bone, an osseous semicircle bifurcated at its extremities, placed between the tongue and the larynx, and bound to these two organs by muscles, which gives unity to their movements in rising and falling. The tongue is formed of muscles, some of which are proper to itself, and others attach it to the hyoid bone, to the lower jaw, and to the styloid process of the temporal bone. All these muscles interlace their fibres in an inextricable manner, especially towards the upper portion of the tongue. At the median line and in the centre they are fixed to a cartilaginous plate, a sort of indirect prolongation of the hyoid bone, which gives greater solidity to the whole. The buccal mucous membrane covers the tongue, and is remarkably dense on its dorsal face.

The complex interlacement of the muscular fibres of the tongue permits a great variety of motion. It can raise or lower itself, lengthen or shorten, shrink or expand, diminish the end to a point, bend itself upwards and downwards, hollow itself into a canal lengthwise or breadthwise, carry its point and its edges to the parts of the mouth into which mastication has dispersed the food; in short, it exhibits in its movements and changes of form great force and the most subtle dexterity.

The tongue receives three nerves; the *great hypoglossal*, the *lingual*, and *glosso-pharyngeal;* the first gives motion, and the last two are the sensitive nerves of taste. Under the influence of the first it takes part in the functions of digestion and in the articulation of sounds, and endowed by the others with a special sensibility, it is the principal organ of taste.

The bottom of the buccal cavity communicates with the

pharynx, a canal with elastic walls formed by muscle, and lined with mucous membrane. It extends from the back of the mouth to the œsophagus, and is the vestibule of this passage, a sort of funnel, the upper part of which shares in deglutition, and adds to the resonance of the voice. The anterior wall of the *œsophagus* is formed by the larynx, the superior orifice of which, surmounted by the epiglottis, opens into the pharyngeal cavity, so that it is only the half of a canal completed in front by the larynx.

The pharynx is continued below by the *œsophagus*, a tube formed by two membranes, the external muscular and the internal mucous. It is extensible and very contractile; it descends between the spinal column and the trachea, which it overlaps a little to the left, and on reaching the thorax it follows the posterior mediastinum, and at last traverses the diaphragm and opens into the stomach.

The stomach.—The form of the stomach has been compared to that of a bagpipe. It is a large pouch, an expansion of the digestive tube, placed transversely across the upper portion of the abdomen. Its left extremity or great cul-de-sac, lying in the hypochondriac region, is rounded and larger than the right, which corresponds to the epigastrium. Above, it forms a concave curve—*the lesser curvature;* below, a convex curve—*the greater curvature.* The opening by which it communicates with the œsophagus is to the right of the great cul-de-sac, and is called the *cardiac* orifice; and that which opens into the intestine, the pylorus, or *pyloric* orifice.

The walls of the stomach are formed of four membranes, which, proceeding from without inwards, are a *serous*—the peritoneum—a *muscular*, a *fibrous*, and a *mucous* membrane. The muscular membrane is composed of three layers of fibres, some longitudinal, others circular. These fibres are slender and open for the most part, but near the pylorus they are closer and stronger, and around this orifice they form a muscular ring, which has been named the *pyloric valve.*

The *intestinal canal* is a continuation of the stomach; its walls, like those of that organ, are composed of four mem-

branes—a serous, muscular, fibrous, and mucous membrane. It is divided into the large and small intestines. The *smaller* intestine is composed of the duodenum, jejunum, and ileum. The *duodenum* is so named because it measures

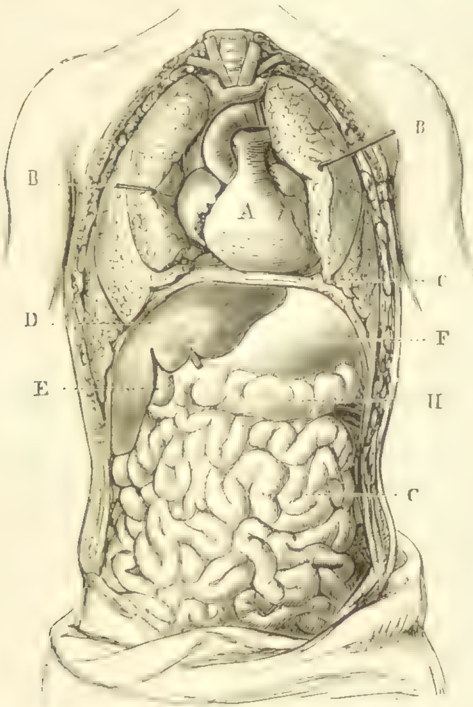


Fig. 23.—Transverse section of the thoracic and abdominal cavities.

A. *Heart.*
B. *Lungs separated to show the heart.*
C. *Diaphragm.*
D. *Liver.*
E. *Gall-bladder.*
F. *Stomach.*
G. *Small intestine.*
H. *Transverse colon.*

nearly twelve finger-breadths in length; it extends from the stomach to the *jejunum*, from which no line of demarcation separates it, nor is the jejunum separated from the *ileum*. These names indicate a purely arbitrary distinction, drawn by the ancient anatomists between these three parts of the intestinal canal. The *large* intestine differs from the small one externally in size, and because it presents a series of more

marked enlargements. The *cœcum* is its upper portion, of a larger calibre than the ileum, and separated from it by the *ileo-cœcal valve*, a fold of the internal membranes designed to prevent the reflux of fluids. It opens into the ileum, not at its extremity, but by a lateral orifice; below this orifice, it forms a sort of ampulla, terminated by the *appendix vermiformis*. The cœcum is followed by the *colon*, from which it is separated only by an artificial division. It is the largest and longest portion of the large intestine; it forms a curve called the *arch of the colon*, and is divided into the *ascending*, *transverse*, and *descending* colon, to which succeeds the *rectum*, the extremity of the intestinal canal.

The total length of the intestine is about nine yards. It occupies a large portion of the abdomen, in which it is folded in numerous *convolutions*.

The *peritoneum* (*peri*, around; *teinein*, to stretch) envelops the intestinal canal, attaches it to the vertebral column by a double membranous fold, called the *mesentery*, and partially covers it by a floating fold or *epiploon*. Imagine a membrane doubled back so as to form a long broad fold. At the bottom of and within this fold lies the intestine, which we may suppose to be stretched in a straight line. The membrane adheres closely to three-quarters of the surface of the intestine, and then folds back on itself. The two leaves of this peritoneal covering are united by cellular tissue, which permits their separation by distension of the intestines. If now we pucker the fold at its root, the border which contains the intestine will form numerous sinuosities, and this is really the arrangement of the intestinal convolutions. In the region of the colon, the fold formed by the peritoneum is very much broader, the intestine lies in the middle of its breadth, and the rest falls like a veil in front of the intestinal mass, and rises to the stomach, which it partially covers as well as the liver and spleen. This moving veil is the *epiploon* (*epi*, upon; *pleo*, I float). That part of the fold behind the intestine fastens itself to the front of the vertebral column, and takes the name of *mesentery* (*mesos*, middle, and *enteron*, intestine).

The *mucous membrane*.—This membrane is to the cavities

which it lines, what the skin is to the surface of the body. It is an internal skin, which is a continuation of the external. Like the skin, it is an organ of absorption and secretion. It is composed of a corium or true skin and a sort of epidermis, named the *epithelium*, variable in its texture and in its elements according as it is to offer more or less resistance. A peculiar fluid—*mucus*—is secreted by this membrane and preserves its softness. The mucous membrane is covered, throughout the digestive canal, even to the end of the small intestine, with great numbers of papillæ or villi, and especially on the tongue. In the stomach it has numerous folds, which are effaced when the organ is distended; and throughout the smaller intestine it forms the *valvulæ conniventes*, wrinkles or folds designed to increase the extent of absorbing surface.

The *liver* is an organ of a glandular nature, and, like all the glands, is designed to secrete a peculiar fluid. It separates from the blood the elements which constitute *bile*. Situated in the right hypochonder, it enters the arch of the diaphragm; and it occupies also a portion of the epigastrium, and then comes in contact with the stomach, the arch of the colon, &c.; behind, it corresponds to the vertebral column, the aorta, and the descending vena cava; in front to the base of the chest. It is held in its place by ligamentous folds of the peritoneum; the most important of these is the *suspensory* ligament. The form of the liver is difficult to describe: its upper surface is convex, its lower slightly concave. It is divided into the right and left *lobes;* to the latter is attached an appendage named *lobus Spigelii* or Spigel's lobe. The under surface of the liver is marked by the *longitudinal* and *transverse fissures.* Through this last the portal vein enters. Examined *en masse*, the liver is of a reddish-brown colour. Its substance is yellowish, granular, and contained in an envelope of cellular tissue called *Glisson's capsule.* Several kinds of vessels are found in it: the *hepatic artery*, which carries the blood which nourishes the organ; the *portal vein*, which carries the blood to the liver which is to be purified; the *hepatic vein*, which transmits to the descending vena cava the blood elaborated by the gland; and lastly, the *bile-ducts*,

which secrete or transport the fluids extracted from the blood by the liver to the *gall-bladder*, situated under the right lobe.

The tissue proper of the liver is essentially constituted by the secretory canals of the bile, each one of which terminates in an *acinus* or lobule; a net-work of capillaries of the portal vein surrounds these lobules, which by their union in clusters form the liver, and which are so many diminutives of that gland. The secretory ducts are continuous with the *hepatic* ducts, and the capillaries of the portal vein with those of the hepatic veins, which transmit to the inferior vena cava the blood from which the bile has been separated. The liver secretes sugar also, which, formed in this gland at the expense of the blood from the portal vein, is immediately decomposed, and in health disappears in the process of nutrition.

Pancreas.—This is an elongated gland situated behind the stomach: it secretes the *pancreatic juice*—a fluid analogous to the saliva, and which the pancreatic canal pours into the *ductus choledochus*, near its orifice in the duodenum.

Spleen.—This is a spongy vascular body situated in the left hypochonder, between the stomach and the false ribs: it serves as a reservoir in over-fulness of the portal vein. Its special use and purpose are unknown.

The *kidneys* are two in number, and are placed on the right and left of the lumbar vertebræ in the lowest part of the hypochonders. They are glands of a peculiar and very complicated structure. They separate the urea from the blood, and transmit to the bladder the urinary secretion by two canals called *ureters.* The upper portion of the kidneys is covered by the *supra-renal capsules*, the use of which is not known.

Mechanism of digestion.—This function consists in the decomposition, liquefaction, and absorption of alimentary substances; it prepares the nutriment by separating the assimilable portions which are to be mingled with the blood from those which are not fit to enter into the organism. The aliments undergo in the mouth the first change necessary to their introduction into the digestive canal, which is also no less important in relation to their chemical trans-

formation. They are here mixed with the saliva, which penetrates them thoroughly, softens and dissolves them in part, and thus renders their mastication, taste, and deglution more easy. The saliva also transforms the amylaceous substances contained in the food first into dextrine and then into glycose or sugar; it reduces a portion of the fatty bodies to an emulsion—that is to say, it separates them into particles held in suspension in the salivary fluid, and begins the decomposition which is completed in the digestive canal.

Digestion in the stomach.—From the mouth the alimentary mass descends through the pharynx and œsophagus to the stomach, where it mingles with the *gastric juice*, one of the most powerful agents of digestion. The gastric juice is secreted by glandular tubes situated in the mucous membrane of the stomach. It is a colourless fluid, saltish as well as acid to the taste. It contains, among other elements, alkaline chlorides, lactic acid, and an organic substance called *pepsine*, which is peculiar to it. The gastric juice pours into the stomach in considerable quantities when food is introduced into it, mingles there with the mass, softens it, and induces a fermentation which results in their ultimate liquefaction. During digestion a characteristic movement takes place in the stomach and intestinal canal—the circular fibres of the muscular membrane contract successively from above downwards, and push the alimentary substances in the same direction. Gradually as the lower fibres contract the upper ones relax in order to contract anew. This is called the *peristaltic movement.* Under its influence the contents of the stomach are kept incessantly in motion, mixed with the gastric juice, and directed toward the *pylorus.* This orifice is so named because it is like a door-keeper to the stomach, allowing the aliments which have been sufficiently elaborated to pass out while the others are retained in the organ. After a time, which varies from three to five hours in different individuals and at different ages, the alimentary mass is converted into a grayish paste, acid, and almost fluid; it then takes the name of *chyme*, and the function of the stomach, *chymification*, is accomplished.

Intestinal digestion.—In proportion as the chyme reaches

the duodenum through the pyloric orifice, the bile and the pancreatic juice mingle with it, as the gastric juice does in the stomach. They both aid in liquefying the chyme by the water which they contain, and by their special action upon the substances of which it is composed: the pancreatic juice continues with even more activity than the saliva to transform the amylaceous matter into glycose. The bile assists the digestion of the animal matter by reducing the fatty bodies to an emulsion, and it appears also to act as an excitant to the function of the intestine; and lastly, a fluid secreted by the mucous membrane of the intestine, as the gastric juice is by the stomach, co-operates with the biliary and pancreatic secretions. Under the influence of these agents, of the fermentation induced by the pepsine and of the peristaltic movement, the chyme is liquefied during its advance through the smaller intestine, and is transformed into a white milky fluid—the *chyle*—which the chyliferous vessels draw from the surface of the mucous membrane, and carry to the *thoracic duct*, from whence it goes to be mixed with the blood.

Absorption.—The moment chyle is formed digestion proper may be considered as accomplished, though on this function also depends the absorption of the chyle, which must still be perfected in its course through the smaller intestine and the veins before it mingles with the blood.

The mechanism of absorption is still unknown. It has been explained as taking place by *endosmosis*—a phenomenon discovered by Dutrochet, which results from the property which tissues possess, under certain conditions, of permitting fluid or gaseous bodies to pass through their capillary canals. If, for example, two fluids which may be mixed, though they may be of different natures and different densities, are separated by a membrane, two currents are established through this membrane in opposite directions, and of unequal force, tending to mix the two fluids, the stronger current is generally produced by the fluid the least dense; and this is called endosmosis—the feebler current *exosmosis*. In this experiment the substances mingle without changing their nature; but it is not so in absorption. The substances absorbed by

the organic tissues change incessantly during their progress, borrowing or lending elements to each one of the molecules through which they pass. And farther, the different tissues absorb more or less of the same substance by virtue of properties which are unknown. In this way a poison which remains inert on the mucous membrane of the stomach is rapidly absorbed by the lungs.

The mucous membranes absorb more rapidly than the skin, and this tissue is more or less permeable according to its thickness, its density, as the epidermis which covers it is thick or thin. Absorption is therefore very rapid in inoculation—that is, when the substance to be absorbed is introduced into the substance of the tissues. Wherever the point of absorption may be, it takes place by the lymphatic vessels, and especially by the veins. The veins absorb a greater number of substances than the lymphatics, and carry them more quickly into the circulation; they charge themselves especially with the materials which are to be rejected from the economy, while the lymphatics absorb from preference those that can still be assimilated. The veins and the chyliferous vessels, which are a variety of the lymphatics, draw from the mucous membrane of the intestine the useful products of digestion; but the lymphatics take possession of fats, while the veins prefer fluids, albumen, sugar, and salts.

It is well known with what rapidity certain substances taken into the alimentary canal, or into the lungs, pass into the other organs, and exhale, or are eliminated. Thus the presence of the ferro-cyanide of potassium has been recognized in the urine within one minute after its ingestion into the stomach. Indigo, gallic acid, and other colouring matters, or those possessing a characteristic odour, pass in the course of fifteen or twenty minutes through all the windings of the circulation.

As has already been stated, absorption takes place much more rapidly by the skin when it has been deprived of its epidermis. Five or six minutes are generally a sufficient time for the alkaloids of opium or belladonna to manifest their action on the nervous system, and in some cases this action is produced in a few seconds. Other substances, especially

sulphate of copper, are almost as rapid in their effect on the stomach as chloroform and several gases when placed in contact with the mucous membrane of the lungs; they produce phenomena which develop themselves with terrible rapidity. Medicine derives great assistance from this absorbent property of the tissues; thanks to which, humanity is daily spared a vast amount of suffering.

CHAPTER VIII.

Respiration.—Thoracic cavity; pleura.—Organs of respiration: lungs, trachea, bronchia.—Respiration; influence of respiration on the blood, Lavoisier's theory, theory of catalytic phenomena; mechanism of respiration, respiratory sounds, frequency of respiration; capacity of the lungs; modification of the air in the lungs.—Influence of atmospheric pressure on respiration; mountain-sickness.

Thoracic cavity.—The thorax or chest, as we have already seen, is formed by the vertebral column, the ribs, and the sternum. The shoulder-blades and collar-bones belong to the arm, which is an appendix of the thorax. The thorax resembles a bony cage (fig. 11, p. 27), the interstices of which are filled with the muscles; the interior of this cage is the thoracic cavity (fig. 21, p. 74). It is the second cavity in point of size in the body; it has the form of a cone, slightly flattened from before backwards, with the base turned downward, and hollowed out in front. It is bounded at its apex by the sternum, the clavicles, the first rib on the right and left, and the seventh cervical vertebra; at its circumference by the sternum, the ribs, and the dorsal vertebræ; at its base by the false ribs, the costal cartilages, and the xyphoid cartilage. The diaphragm corresponds to this base (fig. 21, p. 74); this is a muscular partition, the fibres of which radiate from a central aponeurosis; it closes the chest at the bottom, into which it rises like an arch, a little depressed in the centre. The diaphragm is attached to the cartilaginous border of the false ribs, to the xyphoid process, and to the lumbar vertebræ. This last attachment is effected by muscular fasciculi, which are called the *pillars* of the diaphragm. The central aponeurosis of this muscle is in the form of a

clover leaf; it was considered a nervous centre by the ancients, perhaps because of the pain and the peculiar sensations induced in the epigastrium by strong emotions, or because they confounded the tendinous fibres with the nervous tissue.

Pleura.—The cavity of the chest is lined with a serous membrane, called the *pleura*, which forms in each half of this cavity a sac without an opening. There are therefore two pleuræ, a right and a left. Proceeding from the edges of the sternum and the costal cartilages, the pleuræ cover the lateral walls of the chest and a portion of the body of the vertebræ. They then approach each other, leaving a space between them called the *posterior mediastinum*. On reaching the root of the lungs, they turn from within outward, covering a portion of the pericardium and of the internal surface of the lungs, their posterior borders and external surface; they then penetrate the interlobular fissures, and fold back upon the anterior border of the lungs and upon their internal surface quite to their roots; then turning again forward, they cover the sides of the pericardium, in front of which they turn back to back, and then separating anew, they reach the borders of the sternum from whence they sprang. The space left between the pleuræ behind the sternum is the *anterior mediastinum*, separated, as is seen, from the posterior mediastinum by the heart and the root of the lungs. At the top of the chest the pleuræ form a conical cavity, which receives the apex of the lung; at the bottom they cover the superior surface of the diaphragm. In the posterior mediastinum are the œsophagus, the aorta, the azygos vein, the thoracic duct, and the lower portion of the trachea. In the anterior mediastinum are the pericardium—the envelope of the heart—and the *thymus gland*, an organ whose uses are unknown. That part of the pleuræ which envelops the organs of the chest, and that which lines the walls of this cavity, are thus in contact with each other without adhering, in a normal condition, and they allow the expansion and contraction of the lungs and the walls of the chest. The serous nature of the pleuræ insures freedom of movement, and prevents all roughness in the constant friction of the surfaces.

Organs of respiration. Lungs.—As their name indicates (*pneumon*, from *pneo*, I breathe), the lungs are the essential organs of respiration. They are two in number, though they

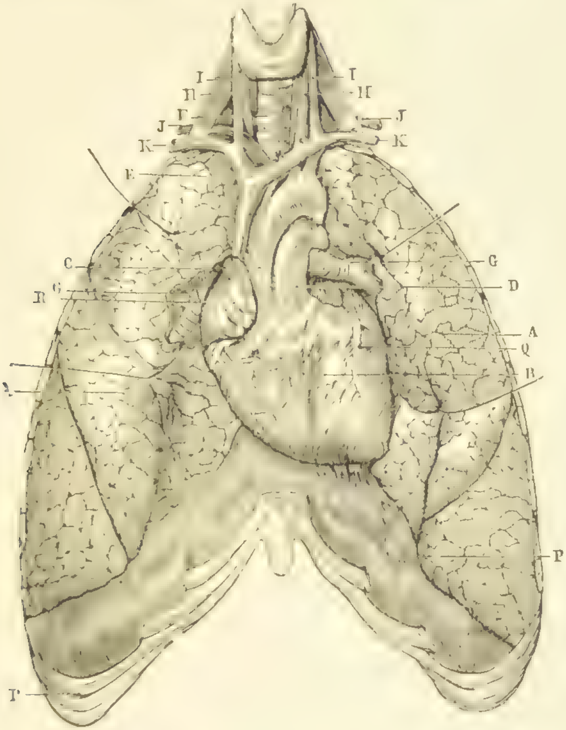


Fig. 24.—Lungs and heart.

A. *Lungs with the anterior edges turned back to show the heart and bronchia.*
B. *Heart.*
C. *Aorta.*
D. *Pulmonary artery.*
E. *Ascending vena cava.*
F. *Trachea.*
G, G. *Bronchia.*
H, H. *Carotid arteries.*
I, I. *Jugular veins.*
J, J. *Subclavian arteries.*
K, K. *Subclavian veins.*
P, P. *Costal cartilages.*
Q. *Anterior cardiac artery.*
R. *Right auricle.*

receive the air by one canal and the blood by a single vessel; they may be considered as the terminal expansion of the ramifications of the trachea, or as the two heads of a single tree. Placed in the chest, of which they occupy the larger part,

and to the shape of which they are moulded (fig. 23, p. 81), they represent two irregular cones, resting their bases on the diaphragm, filling with their apices the two conical spaces lined by the pleura at the top of the chest, and separated by the heart and the mediastinum. The right lung is divided in its length into three lobes by two oblique clefts, and is shorter and larger than the left, which has but two lobes. The internal face of the lungs is concave; about the middle the bronchia unite with the pulmonary vessels to form the root of the lungs; their base takes the form of the convexity of the diaphragm; their edges, thin in front and at the bottom, thick and rounded behind, partially cover the heart, and fill the space which separates the diaphragm from the walls of the thorax, as well as the groove between the ribs and the vertebræ. The entire surface of the lungs is smooth and moistened with serous secretion.

The tissue proper of the lungs, or *pulmonary parenchyma*, is of a grayish rose colour, soft, spongy, elastic, crepitating under pressure in consequence of the air it contains. It is divided into polyhedral lobules, very variable in form and in the disposition of their facets, which permit exact juxtaposition without intervals; and they are separated by partitions of cellular tissue, independent and without communication with each other. Each one of these lobules is formed of a cluster of little cavities called *pulmonary vesicles*, constituting a cul-de-sac, and receiving the air from the bronchial ramifications of which they are the terminal expansions. The diameter of these pulmonary vesicles is from one-seventieth to one hundred and fiftieth of an inch; from this we can judge of the tenuity of their walls, in the substance of which notwithstanding ramify the capillary vessels. Each lobule represents a little lung, a diminutive of the entire organ. A bronchial twig and minute artery run into it, veins and lymphatic vessels leave it. On the surface the lobules appear bounded by their intermediate partitions, and they form a mosaic of which the mottled colouring varies from rose to black. These black particles are principally composed of a carboniferous substance which penetrates the lung either with the air or with the blood, and which is called *pulmonary carbon*.

The lungs are supplied with air through the larynx, trachea, and bronchia. The *larynx*, the organ of the voice, of which we shall speak later, is continuous below with the trachea. This is a cylindrical tube flattened behind; it is composed of a series of cartilaginous rings united by a fibrous membrane,

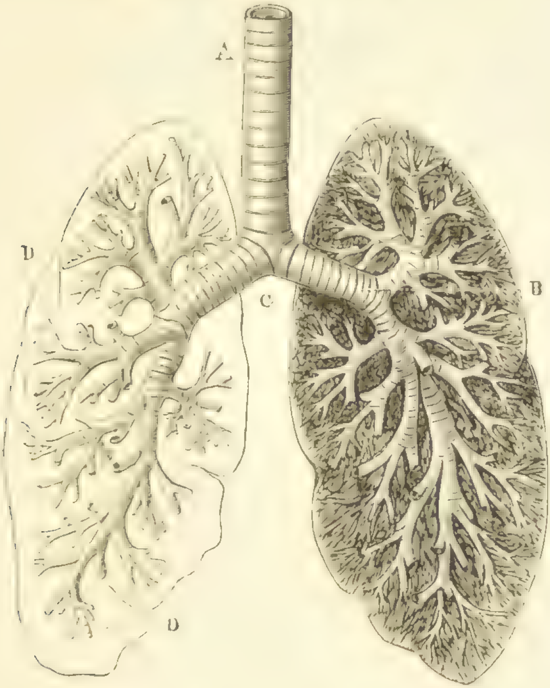


Fig. 25.—Section showing the ramifications of the bronchi in the lungs.
A. *Trachea.* B, C. *Bronchi.* D, D. *Bronchial tubes.*

and lined with a mucous membrane; it is placed in the anterior portion of the neck, and passes vertically from above downward. The rings of the trachea do not extend quite round it; interrupted in their circuit towards the posterior fourth of the tube, they are, properly speaking, only segments of a circle. They number from sixteen to twenty, and produce a corresponding number of protuberances on the surface of the trachea, which is thereby rendered rough and wavy to the touch. It is from this circumstance that it derives its

name (*trachys*, rough). Formerly it was confounded with the arterial vessels, which were supposed also to be designed to contain air.

At the height of the third dorsal vertebra, the trachea divides into two portions, which are called *bronchi*, which on reaching the root of the lungs divide into numerous ramifications designated *bronchia* or bronchial tubes, and becoming more and more slender. Of the two principal bronchi, the right is larger than the left, and the left is twice the length of the right. They are both, as well as their ramifications, up to a certain limit, composed of fibrous membrane and incomplete cartilaginous rings. When their diameter has decreased to less than one-fiftieth of an inch, they no longer have the cartilaginous rings, and the mucous membrane cannot be separated from their walls. They continue to subdivide, and terminate, as already stated, in the pulmonary vesicles, the agglomeration of which in clusters forms the lobules of the lung.

Independently of the artery and pulmonary veins by which the venous blood reaches the lung, and, transformed into arterial blood, is returned to the heart—that is, besides those which serve for the sanguification and circulation—the bronchial veins and arteries carry the blood through the lungs which is destined to nourish the organ itself, and it is probable that the tissue proper of the lung uses for itself part of the red blood formed in its cavities. Numerous lymphatic vessels are also found in the lungs. The nerves which are distributed through the lungs come from the pneumogastric and the ganglionic nervous system.

Respiration.—Respiration is a function by which the oxygen of the air is introduced into the blood, and by which part of the useless and hurtful materials are expelled, in a gaseous form, from the organism. It is divided into two parts: *inspiration*, during which the atmospheric air penetrates the pulmonary cells; and *expiration*, which expels the air which has been changed during its stay in the lungs. On reaching the cells of the lungs, the blood is separated from the air by their walls and those of the capillaries, which ramify over them. However thin these membranes may be,

they suffice to confine the air and the blood in distinct cavities; but like the other organic tissues, they have the property of allowing themselves to be penetrated by endosmosis and exosmosis. The oxygen of the air therefore passes through them in order to combine with the blood; while those gases contained in this fluid, which should be eliminated, separate from it and mingle with the air, which carries them away with it during expiration. It is an interchange of gases between the air and the blood, the air giving up oxygen to the blood, and receiving from it other gaseous fluids, among which carbonic acid gas predominates in volume. This being in excess in the venous blood is exhaled from the lungs, while the oxygen of the air combines with the blood which is carried to the heart by the veins, which has been deprived of a part of its nutritive elements, and has become unfit to support life. On coming in contact with the oxygen, the venous blood loses its dark colour, becomes a brilliant red, and returns to the heart transformed into arterial blood. This group of phenomena is called sanguification.

On the one hand the oxygen of the atmosphere burns carbon in the lung, on the other the lung exhales carbonic acid gas, nitrogen, and the vapour of water. From whence are these gases and this water derived? The carbonic acid gas is not produced in the lungs alone. The venous blood reaches the organ of respiration poor in oxygen, and charged relatively with the carbonic acid gas which it has received in its course from all the tissues; everywhere this acid has been produced by the combination of the carbon with the oxygen, which in the lung is borrowed from the air, but everywhere else it comes from the arterial blood. In a word, the oxygen combined with the blood by respiration, is separated from it little by little in the capillaries throughout the whole body in order to produce numerous products, among others carbonic acid gas. On leaving the heart and in the arteries, the blood contains 24 parts of oxygen per 1000, in the veins it contains only 11 per 1000. As for the nitrogen and the vapour of water, one is disengaged, and the other produced during this same process of nutrition, and both are drawn

from the principles in the organism which are introduced into it by digestion or respiration.

Lavoisier was the first to demonstrate the absorption of oxygen by respiration, and to show by experiment the analogy existing between combustion and respiration. "Respiration," said he, "is nothing but a slow combustion of carbon and hydrogen, which resembles, in every respect, that which takes place in a lamp. . . . In respiration, as in combustion, it is the atmosphere that furnishes the oxygen. . . . But since, in respiration, it is the substance of the animal itself, it is the blood which furnishes the combustible, if animals do not regularly repair by alimentation that which they lose by respiration the oil in the lamp will soon be wanting, and the animal will perish as the lamp will go out for the want of nourishment." Most physiologists have admitted Lavoisier's theory, and they consider respiration a slow combustion of the materials of the blood by the oxygen of the atmosphere, and as the source of *animal heat*. We have just seen that this combustion takes place, not only in the lungs, but throughout the whole extent of the organs where the arterial blood carries the oxygen which presides over the phenomena of nutrition, that is, over the assimilation of the elements of which the blood is formed, and over the decomposition of some of these principles of which certain parts only remain in the system, while others return to be burned in the capillaries of the lungs, or to be exhaled in the form of gas or vapour of water.

Some authors again do not admit that combustion takes place in respiration, the phenomena of which, of quite a different order according to them, may be attributed to a reaction induced by the contact of organized substances. The decomposition and disassimilation of these are due to a series of acts of which very little is known, and which are compared to what has been termed by Berzelius "*catalytic phenomena*." But we confine ourselves to a mention only of this doctrine, which is not generally accepted.

Mechanism of respiration.—We have seen that respiration is divided into two movements—inspiration and expiration. In *inspiration*, the diaphragm contracts and sinks down, push-

ing the abdominal organs downward. The ribs rise by the contraction of numerous muscles; at the same time with the sternum, which is carried forward, the intercostal spaces enlarge, and the chest is developed in all its dimensions, vertically, antero-posteriorly, and transversely. In *expiration*, the inspiratory muscles relax, and others, especially those of the abdomen, lower the ribs and the sternum by contracting the chest; while the lungs, distended by the air inspired, collapse under the pressure of the thoracic walls and their own proper elasticity. The experiments of Duchenne of Boulogne tend to prove that this contraction of the lungs is due to the muscular fibres which accompany the bronchia down to their minutest ramifications.

Nearly all the inspirations are effected by the movements of the diaphragm and the inferior ribs only. From time to time a deeper and more complete inspiration causes the thorax to rise, not simultaneously but successively at the base, then at the apex. In the first case the respiration is *diaphragmatic;* when the lower and middle ribs are raised it is termed *lateral;* and lastly, when the first rib and clavicle take part in the movement, it is costo-superior or *clavicular*. In diaphragmatic respiration, as M. Mandl has observed, the larynx is immovable, the inspiration is easy, without effort, and permits exertion in singing or in gymnastics for a long time and without fatigue. On the contrary, persons who respire principally by the upper ribs are easily fatigued, and very soon out of breath. This is seen in women when the corset compresses the base of the chest, and in singers who adopt, on erroneous principles, the bad habit of clavicular respiration. In this last method of inspiration the larynx is drawn down by the contraction of the external muscles, and its action becomes painful. The effort of the inspiratory muscles rapidly induces fatigue, and the inspiration, always incomplete, becomes also more frequent. Diaphragmatic respiration is practised by mountaineers, gymnasts, and skilful singers—a habit induced either by instinct, or a well-directed education.

The respiratory movements are not completely under the control of the will. It is not possible long to suppress the

contrary movement after an inspiration, and when expiration has taken place the need of inspiration soon makes itself imperiously felt. It is impossible, in fact, to retain the breath except for a very short space of time, two or three minutes at the longest: the most thoroughly trained divers not being able to exceed this limit.

Respiratory sounds. — In a normal condition, and when awake, respiration takes place without noise when the movement is moderate; but when inspiration and expiration are strong and deep, it is accompanied by a noise caused by the air passing through the nasal passages or the mouth. During sleep the column of air breaks against the soft palate and produces snoring. Besides these sounds, which are exterior to the chest, there are others produced by the passage of the air through the bronchial tubes; and when the ear is applied to the chest of a person in good health, a soft and regular murmur is heard in rhythm with the respiration: this is called the *vesicular murmur.* Several morbid causes change the nature of this murmur, suppress it, or produce others. These are so many signs which enable the physician to determine the condition of the respiratory organs.

Frequency of respiration.—In an adult in a condition of repose, respiration takes place about eighteen times a minute. in the infant it is more frequent. As is well known, it becomes very active under the influence of bodily exertion. or under excitement from any cause whether physical or moral. When, on the other hand, the attention is fixed on a laborious effort, the breath is held so that it very soon becomes necessary to take long and deep inspirations to compensate for the insufficiency of those which preceded. This result of hard work or great strain of mind should be guarded against in children, as their constitution suffers greatly under the influence of incomplete respiration.

Capacity of the lungs.—It is estimated that the lungs of a man from thirty-five to forty years old will contain about 225 cubic inches of air; it is less before that age, and falls to a little less than 200 cubic inches at sixty years of age. The capacity is smaller in women, and varies also according to the individual. It is only possible to obtain approximate

experimental results, as the lungs are not completely emptied at each expiration, and the cells always retain a quantity of air, and this quantity is greater in proportion as the respiration is calm and shallow.

Changes on the air in the lungs.—It is clear from the foregoing, that the air which is expired has neither the same volume nor the same proportion of constituent elements as the air which is inspired. In fact, an adult man absorbs by respiration from 450 to 550 grains of oxygen in an hour. He exhales in the same time 632 grains of carbonic acid; a less quantity of nitrogen, amounting to about a hundredth of the oxygen absorbed; and lastly, about 9720 grains of water in the form of vapour. This exhalation of water by the lungs constitutes the pulmonary perspiration, a function analogous to the perspiration of the skin. The expired air, as already stated, is deprived of a portion of its oxygen, and is charged with carbonic acid gas. The proportion of this gas is about 4 parts in 100. From 350 to 400 cubic feet of air are taken into the lungs in 24 hours, and rapidly changed, and the gravest consequences result from placing a man under conditions in which the air cannot be renewed. During the English war in India in the last century, one hundred and forty-six prisoners were shut up in a room scarcely large enough to hold them, into which the air could only enter by two narrow windows; and at the end of eight hours only twenty-three remained alive, and these were in a most deplorable condition. Percy relates that after the battle of Austerlitz, three hundred Russian prisoners were confined in a cavern, and two hundred and sixty of these unfortunates perished in a few hours from asphyxia.

Influence of the pressure of the atmosphere on respiration. Mountain-sickness.—It is well known that the density of the air diminishes with the atmospheric pressure, that is, in the lower regions of the air, on the sea-coast for example, the air is denser than in elevated regions. Thus in order to absorb the quantity of oxygen necessary for sanguification, it is necessary to respire oftener upon high mountains than when on plains, but this acceleration of respiration is perceptible only when the height is considerable and the

distance rapidly passed over. Gay-Lussac, who in his balloon ascension rose to a height of 22,956 feet in six hours, found his respiration disturbed, and greatly accelerated; and having made no movement requiring exertion, he could only attribute this condition to the diminution of the pressure of the atmosphere. But in climbing mountains the movement and efforts of walking are added to the influence of the height; and when the difference in altitude in one day amounts to 6560 feet, a notable acceleration of respiration and quickening of the pulse is observed, which in many instances is accompanied by a peculiar sense of uneasiness, which has been termed *mountain-sickness*. The most remarkable symptoms are fatigue or rather partial paralysis of the muscular system, and especially of the muscles of locomotion. This paralysis of the legs increases with every step until, having gone a certain distance with increasing difficulty, it is impossible to take another step. A rest of a few seconds is sufficient for the muscles to regain their power, and it seems as if the traveller could go on without fear of a recurrence of the difficulty; but very soon it returns, and a fresh halt is necessary. The higher one goes the shorter the distance that can be passed without resting—from one hundred and fifty steps the distance falls off to one hundred—to fifty—and at last to twenty or thirty. Inclination to sleep, oppression of the heart, and loss of spirit are sometimes added to this periodic exhaustion of strength, and in some persons mountain-sickness is closely analogous to sea-sickness. In others the symptoms are such as are always induced in the respiration, circulation, and in consequence in the muscular system, by violent exercise. Thirty steps in climbing a high mountain cause as much fatigue as a forced march or run on a plain. Respiration, quickened by motion and disturbed by successive efforts, is no longer sufficient for sanguification; the proportion between the venous and the arterial blood is no longer normal; and, above all, sanguineous congestion, which is inseparable from violent exertion, takes place in the lungs, in the brain, and other organs. But as soon as the muscles have relaxed for a few moments, two or three full inspirations rapidly relieve the congestion, while a flood of

arterial blood proceeds from the heart to revive the whole organism.

Up to a height of 16,400 feet, man can easily acclimatize himself to the rarefied air. Baron Humboldt saw Peruvians cultivating the land at Antisana, situated 13,454 feet above the level of the sea; and agricultural labour requires the development of an amount of force incompatible with mountain sickness, even though an energy like that of our European cultivators may not be found. Jacquemont visited villages in Thibet at a height of 16,400 feet. La Paz is situated on the Andes at a height of 12,195 feet, but the inhabitants suffer no inconvenience from the rarity of the atmosphere; though strangers can walk only a short distance without stopping, and they are specially uncomfortable if the young Peruvian ladies mischievously invite them to a few turns in a waltz. It is hardly necessary to remark that these symptoms are not equally urgent in all those who expose themselves to this rarefied air. Some individuals scarcely feel them, and are soon acclimatized, while others suffer greatly for a long period. A host of circumstances and special conditions contribute also to render these symptoms more or less marked, and mountaineers themselves sometimes experience them as well as the inhabitants of less elevated countries.

CHAPTER IX.

Circulation.—Organs of the circulation; heart, pericardium; arteries, capillaries, principal arteries; veins, principal veins; portal system; lymphatic vessels and ganglia.—Mechanism of the circulation; discovery of the circulation, action and sounds of the heart, arterial circulation, pulse, capillary circulation; venous circulation, valves of the veins; discharge of chyle and lymph into the veins. Sanguification; circulation in the pulmonary artery, capillaries, and pulmonary veins.—Influences which accelerate or retard the beating of the heart.

Circulation.—The blood is carried by the arteries from the heart to all the organs, and it returns by the veins from all the organs to the heart. This movement of the blood to and from every portion of the body, from the heart as the point of departure, is called the *circulation.* The transportation of chyle and lymph by the lymphatic vessels, which are the tributaries and purveyors of the sanguiferous system, is connected also with the circulation.

Organs of the circulation.—The *heart* is a hollow muscular organ, nearly in the form of a cone, of which the base is equal to the height, and about the size of the fist in the adult. It is situated towards the middle of the chest, a little to the left (fig. 24, p. 91), and between the pleuræ, which contribute to form its covering. Its apex is directed downward, forward, and towards the left, at about the level of the fifth rib; its base looks upward, and slightly backward, and is protected by the sternum. Its anterior face, turned upward and to the right, is marked by a longitudinal furrow, as is also its posterior face, which is turned downward and to the left. Internally the heart is divided by a muscular partition into two nearly equal halves, placed back to back, and

these are each again divided laterally into two cavities, the superior called the *auricle*, and the inferior the *ventricle*. The auricles take their name from a flattened appendage which

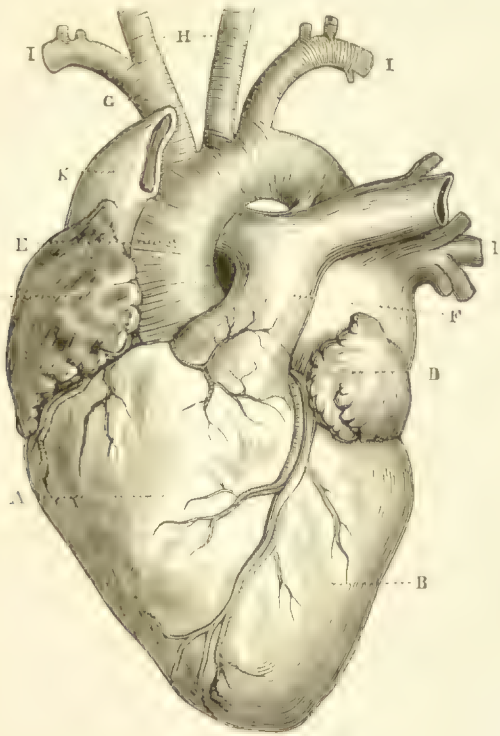


Fig. 26.—Heart and principal arterial and venous trunks.

A. *Right ventricle.*
B. *Left ventricle.*
C. *Right auricle.*
D. *Left auricle.*
E. *Aorta.*
F. *Pulmonary artery.*
G. *Brachio-cephalic trunk.*
H. *Carotid, right and left.*
I, I. *Subclavian arteries.*
K. *Superior vena cava.*
L. *Pulmonary veins.*

falls down upon their external face. The right auricle communicates with the right ventricle, and the left auricle with the left ventricle. There is no communication between the ventricles, but before birth the two auricles communicate by an orifice, which is obliterated during the first months of life,

leaving as the only trace of its existence a depression called the *fossa ovalis.*

The superior and inferior vena cava open into the right auricle, and at the orifice of the latter is the *Eustachian valve.* The orifices of the right and left pulmonary veins are in the left auricle.

The opening by which the auricles and ventricles communicate with each other is called the auriculo-ventricular opening. These orifices are furnished with valves; that on the right is called the tricuspid valve, from the three angles which are formed by its leaves; and that on the left is called the mitral valve, from the slight resemblance which it bears to a bishop's mitre.

The cavities of the heart are lined by the *endocardium*, a very fine, smooth membrane, which has been compared to the serous membranes. These cavities present numerous inequalities, which result from the projection of the bundles of muscular fibre which point in every direction. In the ventricles these fascicles form fleshy columns (*columnæ carneæ*), disposed in a net-work running from one point of the walls to another, and several which take part in the movement of the valves, send out to these valves a crowd of little tendons. The walls of the left ventricle are much thicker and more resistant than those of the right ventricle.

Pericardium.—This is the term applied to the covering which envelops the heart; it is a sac composed of two layers, a fibrous membrane on the outside, and a serous membrane on the inside. This last covers the external surface of the heart, and is reflected back upon itself in order to form, like all the membranes of this nature, a sac without an opening. The heart is thus covered by the pericardial sac, but not contained inside its cavity. A correct idea may be formed of the disposition of the pericardium around the heart by recalling a very common and very convenient, though now discarded head-dress, the cotton night-cap. The pericardium incloses the heart exactly as this cap covered our forefathers' heads.

Arteries.—The vessels which carry the blood from the right ventricle to the lungs, and from the left ventricle to the

whole system, are called arteries. The first-named, the ramifications of the pulmonary artery, contain the dark blood which is carried to the lungs to be oxygenized by contact with the air. It is on the contrary red blood which runs in the aorta, the original trunk of all the arteries distributed

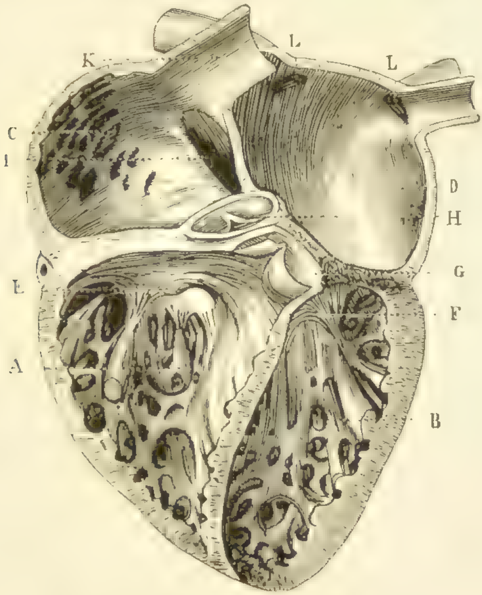


Fig. 27.—Transverse section of the heart.

A. *Right ventricle.*
B. *Left ventricle.*
C. *Right auricle.*
D. *Left auricle.*
E. *Right auriculo-ventricular orifice and tricuspid valve.*
F. *Left auriculo-ventricular orifice and mitral valve.*
G. *Origin of the pulmonary artery and sigmoid valves.*
H. *Origin of the aorta, and valves.*
I. *Orifice of inferior vena cava.*
K. *Superior vena cava.*
L, L. *Orifice of the pulmonary veins.*

through the body. There are two classes of arteries, one pertaining to the pulmonary system or lesser circulation, and the other to the aortic or general circulation. We will first consider the last-named.

The ancient anatomists, finding the arteries empty after death, believed that they were designed to contain air, and from this circumstance they derive their name (*aer*, air, and

terein, to contain). For the same reason, and with more accuracy, they named the tube which conveys the air to the lungs the trachea-artery.

Galen discovered the presence of blood in the arteries, but he retained the name, and others have continued it, although it does not accord with their functions.

The walls of the arteries are composed of three superposed *coats*. The outer one is fibro-cellular, vascular, and very resistant; the middle one, the membrane proper or elastic, is less resistant, and changes its texture under the influence of age or other causes. The inner is extremely thin, and is analogous in texture to the endocardium. When a ligature is applied to an artery, the internal and middle coats are broken through by the pressure, but the external one resists it.

The arteries communicate with each other in their course through the body, and especially toward the extremities by numerous *anastomoses*—that is, they join each other either by means of branches, or by forming a net-work, the meshes of which, rounded and in arches, are closer in proportion as the twigs are smaller. They terminate in innumerable microscopic ramifications, called the capillary vessels, which are intermediate between the ends of the arteries and the veins.

The walls of the arteries are nourished, like all other parts of the body, by the *vasa vasorum*, or vessels of the vessels. And lastly, the arteries are enveloped in their course by numerous nervous filaments from the great sympathetic nerve, and by lymphatic vessels.

The arteries which penetrate the substance of muscles, like those of the thigh and leg, are protected by an aponeurotic sheath, and by fibrous rings which prevent them from being pulled out of place or compressed during the contraction of the muscles which surround them.

Principal arteries.—The *aorta*, which is the main trunk of the arterial system which carries the red blood, is the largest artery in the system. It commences at the upper portion of the left ventricle, not far from the ventriculo-aortic orifice; it has three valves, called the sigmoid or semi-lunar valves,

which serve to prevent the reflux of the blood, and which completely close the vessel when expanded.

The aorta runs upward and to the right, and is here the *ascending aorta;* then it turns to the left, passing in front of the spinal column, and taking a new turn downward, it forms the *arch of the aorta;* it runs along and to the left of the spine through the posterior mediastinum, and is called the *descending aorta*, and passes through the opening in the diaphragm. On reaching the abdomen it becomes the *abdominal aorta*, up to about the fourth lumbar vertebræ, where it bifurcates and forms the two primitive iliac arteries.

From its upper portion the aorta throws off important branches, of which the principal are the following:—The *brachio-cephalic* or *innominate* artery, which springs from the arch, and is its representative on the right side of the chest. This trunk gives off the right *common carotid* and *subclavian;* the left *common carotid* and *subclavian* spring directly from the arch of the aorta.

The *common carotid arteries* run upward along the outside of the neck on a level with the upper border of the thyroid cartilage, and each divides into the *external* and *internal carotid.*

The *external carotid* gives off the *superior thyroid*, the *facial, lingual*, and *occipital* arteries. At the level of the condyle of the jaw it divides into the *temporal* and *internal maxillary.*

The *internal carotid* runs upward along the cervical vertebræ, enters the skull, gives off the *ophthalmic* artery, and is distributed through the brain.

The *subclavian* runs outside, behind and below the clavicle, as its name indicates, and gives off, among other branches, the *vertebral artery*, and the *internal mammary;* and on reaching the arm-pit *(axilla)* it takes the name of the *axillary* artery, and gives off important vessels to the shoulder and chest; and then descending along the humerus under the name of the *brachial* artery, it divides below the elbow, and forms the *radial* and *ulnar* arteries, which furnish the vessels of the fore-arm and those of the hand.

Among the arteries arising from the descending aorta we

will mention only the *cœliac* trunk, which divides into three branches, destined to the liver, the stomach, and the spleen; the superior and inferior *mesenteric*, which go to the mesentery and intestines; and the *renal* or emulgent arteries.

Iliac arteries.—The common iliac arteries, formed by the bifurcation of the aorta, run obliquely downward to the right and left. After attaining a length of about two and a half inches, each one divides into the *internal iliac*, which ramifies on the inside and on the outside of the pelvic cavity, and the *external iliac*, which at the point where it leaves the pelvis gives off the *epigastric artery*. This artery runs upward behind the anterior wall of the abdomen, and unites by anastomosis with the lower extremity of the internal mammary artery. On leaving the pelvis the external iliac takes the name of the *femoral artery*, gives off large branches to the muscles of the thigh, and on reaching the lower third of this region, becomes the *popliteal* artery, or artery of the ham. This last gives off the *anterior tibial*; and then divides into the *posterior tibial* and the *peroneal* artery. The anterior tibial at the point of the articulation of the foot with the leg takes the name of *dorsal artery of the foot*, and ramifies over the upper surface of the foot; while the peroneal and posterior tibial, after having, like the anterior tibial, distributed branches to the leg, terminate in the plantar region, or sole of the foot.

Veins.—The veins carry the blood from the extremities to the heart. They are divided like the arteries into two classes, according as, filled with red blood, they run from the capillaries of the lungs to the trunks of the pulmonary veins—which is the *lesser circulation;* or as they carry the black blood to the venæ cavæ—which is the *general circulation*. The veins of the liver and their principal trunk, the *portal* vein, have sometimes been considered as also a separate system; and this distinction has also been extended to those of the kidneys and other organs.

The walls of the veins are much thinner than those of the arteries, and are formed of four tunics, of which the fourth or internal one is like that of the arteries; the others are formed of elastic or cellular fibres, longitudinal in the third, circular in the second, in such a manner as to present the

greatest resistance. The third and fourth coats form folds, which when extended partially close the vessel. These *valves* are disposed in such a manner as that when the blood moves toward the heart it presses them close to the walls of the veins, and they are no obstacle to its course; while, if it moves in the contrary direction, they close and prevent its return toward the extremities. The veins are disposed in two planes. Some are deeply placed, and accompany the arteries, of which they are called the companions (*venæ comites arteriarum*); others are superficial, and creep along under the skin without any coincidence with the direction of the arterial vessels. Springing from the capillaries, by means of which they communicate with the arteries, the venous radicles unite more rapidly than those of the arteries into considerable branches, superior in numbers and total capacity to the arterial trunks. Many of the arteries, in fact, are accompanied by two veins as satellites, of at least equal calibre; and the superficial veins show still greater disproportion. In the interior of the cranium the veins are transformed into *sinuses* or canals formed by the dura mater, which receive the venous branches of the brain. The veins are enveloped in their course by numerous lymphatic vessels.

Principal veins.—The superior and inferior vena cava are to the venous system what the aorta is to the arterial system.

The *superior vena cava* receives the blood from the head, neck, the upper extremities, and the walls of the chest; it opens into the right auricle of the heart. It is formed by the two *brachio-cephalic* trunks and the *azygos* vein. Each of these brachio-cephalic venous trunks unites, like the arterial trunks of the same name, all the principal veins of the head and the arms, which are the two jugulars, internal and external, and the subclavian.

The *internal jugular* corresponds to the carotid artery; it receives the blood from the sinuses of the dura mater, from the veins of the head, of the neck, and part of the shoulder. The *external jugular* carries the blood from a part of the superficial veins of the head to the subclavian vein.

The *subclavian vein* corresponds to the artery of the same name, and receives the companion veins, and veins corre-

sponding in name to the arteries of the upper limb; it is also the common trunk of the superficial veins of the hand, fore-arm, and arm, the principal of which are the *cephalic* and *basilic.* This last vein crosses the radial artery in the bend of the elbow, and is separated from it by a tendinous expansion of the biceps muscle. The cephalic and basilic veins are those most commonly opened in blood-letting; this operation is rendered delicate by the situation of the basilic, which exposes the artery to the danger of being wounded.

The *azygos vein* (*azygos*, without a fellow) forms the communication between the superior and inferior vena cava. It rises vertically in the posterior mediastinum and to the right of the spine, and about the level of the seventh rib it receives the *lesser vena azygos*, which comes from the abdomen.

The inferior vena cava opens into the right auricle under the superior vena cava. It is the common trunk of all the veins coming from the parts below the diaphragm, and is formed by the union of the two iliac trunks, companions of the iliac arteries; it runs up vertically to the right of the spine as companion vein to the aorta, and receives the veins of the abdomen. Its primitive branches, the iliac trunks, are formed by the union of the veins of the pelvic cavity and of the lower extremities, companions of the arteries of the same name. Among the superficial series of veins, which are also tributaries to the main iliacs, are the external and internal *saphenous* veins, which run from the foot to the top of the thigh. These two veins are plainly visible on the front of the ankle and on the calf.

Portal system.—An arrangement of veins peculiar to the abdomen, and especially to the liver, is designated by this term. The *portal vein* is formed by the union of the veins of the mesentery, spleen, stomach, and intestine; it transmits the blood from these organs to the liver, from whence it is poured into the inferior vena cava.

Lymphatic vessels and ganglia.—This is the name given to a special circulatory apparatus composed of very delicate vessels with transparent walls and of *ganglia* or *glands*, which appear to be formed by these vessels, some of which terminate in and others spring from them.

The lymphatic vessels have a very irregular course, and exhibit numerous swellings which are owing to valves. They exist in every part of the body, and transport the chyle and the lymph, drawn by their microscopical roots from the surface of the mucous membrane of the intestines, or from the tissues of the organs. They accompany the blood-vessels in their course, especially the veins, and they are also found in great numbers at the surface of the body in regions abounding in subcutaneous veins, as in the limbs, face, and neck. They are very numerous in the mesentery and around the intestines; they unite in two principal trunks or reservoirs, one of which is the *thoracic duct*, which rises through the chest at the left of the spine, and opens into the left subclavian vein, the other is called the *great right lymphatic vessel* (ductus lymphaticus dexter), which runs parallel with the first, and opens into the right subclavian vein.

Mechanism of the circulation.—Galen was the first to discover that the arteries contained blood and that they communicated with the veins, but he went no farther than this. In 1553 Michael Servetus, guessing, so to speak, the phenomena of the pulmonary circulation, indicated very exactly the course of the blood and its elaboration in the lungs by contact with the air. But the doctrine of Servetus rested neither upon proof nor experiment, it resulted from a sort of intuitive perception of the facts, and he was not aware either of the impulsive force of the heart or the action of its valves.

Other physiologists, like Servetus, had glimpses of the truth and added new discoveries to his; in fact, most of the phenomena of the circulation had been suspected or indicated at the commencement of the seventeenth century, but all the knowledge on the subject was but a chaos of facts and reasonings without unity, and often contradictory. It required the genius of Harvey to extract from this chaos a simple and irrefutably demonstrated *system.*

Movements and sounds of the heart.—The heart, the principal agent of the circulation, is the source of movements which are not under the control of the will, but which are constantly influenced by moral impressions and by sensations. These movements consist in the alternate contraction and relaxa-

tion of the walls of the heart, that is in the opening and shutting of its cavities. The ventricles contract simultaneously, then to this contraction succeeds a period of relaxation, during which the auricles in their turn contract, to relax during a new contraction of the ventricles. The dilating movement is called the *diastole*, and the contracting the *systole*. During the diastole the blood flows into the cavities of the heart, to be expelled by the systole; the contraction of the auricles forces it into the ventricles, that of the ventricles throws it into the aorta and the pulmonary artery.

The contraction of the ventricles modifies the form of the heart. Its transverse circumference is ellipsoid during the diastole, and becomes circular during the systole; the antero-posterior diameter being thus greater, the point of the heart strikes the anterior wall of the chest, and if the ear be applied to this point, a dull sound will be heard at the moment of the shock, and about half a second after, a clearer sound is heard, coincident with the relaxation or the diastole of the ventricles. The mechanism of these sounds has been variously explained; they seem to be owing, the first to the sudden closing of the tricuspid and mitral valves at the moment when the ventricular systole throws the blood into the aorta and pulmonary artery; the second to the closing of the sigmoid valves during the ventricular diastole, under the influence of the elasticity of the arteries, which tends to cause a reflux of the column of blood.

The alternation of the systole and diastole constitute the rhythm and regularly marked beating of the heart which makes itself heard and felt through the walls of the chest. We will follow these movements in their evolution and the blood in its course.

Arterial circulation.—The left ventricle, in contracting, pushes the red blood which it contains in the direction of the auriculo-ventricular orifice and toward the orifice of the aorta,—but the mitral valve is so placed that it closes under the impulse of the moving blood, which is thus forced into the aorta and from thence into all the arteries, in which its motion is caused by the triple action of ventricular contraction, and of the elasticity and contractility of the arterial

walls. In vessels of a certain calibre this movement is jerking and rhythmical, precisely like that of the heart, and if we place the finger on the course of an artery we feel the shock of the blood, or the *pulse.* The pulse and the beating of the heart are synchronous, that is, they take place simultaneously, or rather with an interval so short as to be imperceptible. But in proportion as the blood advances through the arterial ramifications, the numerous changes of direction which it undergoes and the friction between it and the walls of the vessels diminish the force of its impulsion; and at last, on reaching the capillary vessels it flows continuously and without shock.

In examining, under a microscope, a vascular membrane belonging to a living animal, the circulation of the blood through the capillaries is plainly visible. The largest of these canals allow the column of blood to pass rapidly, in the smallest ones its course is slow and the blood-globules can only pass one by one; they float in a transparent fluid, and sometimes a globule becomes entangled obliquely across the calibre of the vessel and stops until another comes to push it forward. Malpighi was the first to verify in this manner the accuracy of Harvey's theory, forty years after it had been propounded by the illustrious English physiologist.

The different causes, therefore, which accelerate or retard the contractions of the heart, influence the motion of the blood in the arteries; and farther, the contractility of these vessels may be influenced by local causes, and the movement of the blood is modified so as to be either retarded or quickened, as they are contracted or relaxed. In the first case the afflux of blood is not sufficient to excite the organs, which become sluggish and partially paralyzed; in the second it is so great as to cause an abnormal activity of the function. And lastly, we all know that the repose or action of the muscles has the effect of retarding or accelerating the circulation, general or local, which, in the course of time, results in the diminution or increase of the muscular strength.

It is in the capillaries, in fact, that arterial blood yields to the tissues the elements of which it is composed, and which it delivers to them for assimilation, in order to receive in

exchange the disassimilated particles which are to be rejected from the system or submitted to a fresh elaboration. A living and nourishing fluid, it carries to the organs life, heat, and the elements of nutrition.

Venous circulation.—After passing through the capillary vessels, the blood passes into the venous radicles. At its entrance into the aorta and during its course through the arterial system, it was of a brilliant red colour, now it has become dark; the arterial or red blood is changed to venous or black blood; deprived of the greater portion of its constituent elements it returns to their source for a fresh supply.

The blood moves in the veins from the impulsion received originally from the heart; this force is designated by the term *vis a tergo*, because it is exerted behind the fluid column. The elasticity of the veins, and their contractility also, contributes to urge the blood along in its return towards the heart, but it is the valves which most effectually second the cardiac impulse by opposing the reflux of the blood toward the arteries. If a moderately tight ligature be placed around the arm, the veins begin to swell because of the afflux of blood, which can neither go on toward the heart because of the ligature, nor return toward the arteries because of the valves which oppose it in that direction. If the finger be now passed lightly over the course of a vein in a direction opposed to the circulation, the little nodules which mark the projections caused by the distended valves are easily distinguished. Thanks to the play of these valves, any pressure upon the veins, from muscular contraction, or whatever cause, can only carry the blood toward the heart, while without them it would be impelled indiscriminately one way or the other. Therefore the valves are more numerous in the veins which are connected with the muscles: in the deep veins of the limbs, for example, than in those which creep along under the skin.

Gravitation affects the movement of the venous blood, which is much less rapid than that of arterial blood. When the hands hang down for a long time as in walking, they swell so much that the flexion of the fingers is difficult, and

it is the same with the feet and legs after long-continued standing, and varicose veins appear on the limbs of persons whose profession obliges them to remain on their feet.

In following the course of the blood on its return to the heart, we find a venous system belonging to the liver and intestines; the *portal system*—to which reference has already been made—which carries the venous blood from the digestive canal and from the spleen to the liver. This system is remarkable from the fact that it is ramified at both extremities; at the intestinal extremity the radicles or roots, and at the hepatic the branches, are found. From this it has been inferred that the bile is secreted from the blood of the portal vein and not from the blood of the hepatic artery; but this question still remains unsettled.

The inferior vena cava, after receiving the blood from the lower regions of the body, turns toward the heart like the superior vena cava, but before reaching it, the blood receives by the subclavian veins the lymph and chyle which have been brought to it by the two grand trunks of the lymphatic system; the elements of nutrition drawn from the intestine come to replace those which have just been given up for assimilation. Thus partially reconstituted, the blood pours back through the venæ cavæ into the right auricle of the heart, and the auricle by contracting throws it into the right ventricle.

At last the blood has returned to the heart, and although it is enriched by the assimilable products of digestion, it is still incomplete, and must be transformed in order to become perfect arterial blood, while at the same time the combustion of a portion of its principles will produce the heat which is soon to be distributed to the organism. It is in the lungs that this elaboration of the blood is to take place—*hematosis* or *sanguification.*

Pulmonary circulation.—The right ventricle contracts, and the flood of venous blood closes the tricuspid valve, and passes into the *pulmonary artery*. This artery and all its ramifications contain black or venous blood, while the pulmonary veins, as we shall soon see, convey red or arterial blood; it is therefore to their *direction*, from the heart to the

lungs, or from the lungs to the heart, that the vessels of the pulmonary circulation owe their names. The pulmonary artery, like the aorta, is provided at its orifice with three valves, called *sigmoid* or semi-lunar valves. From the right ventricle to the ramifications of the pulmonary artery the blood has but a short distance to pass, and it meets with no resistance at all comparable to that encountered in the systemic arterial circulation. The walls of the right ventricle therefore are much thinner than those of the left, and consequently have less power. In the capillaries of the lungs the motion of the blood varies in quickness according as the respiration is easy, or retarded by any obstacle, or by the presence of air unfit for the performance of the respiratory functions. The capillaries are distributed through the substance of the lungs in such a manner that they correspond to the pulmonary cells. (See *Respiration*, p. 92.) It is in these ultimate divisions of the lungs that the oxygen of the air combines with the venous blood charged with carbonic acid, and transforms it into arterial blood. The reddish-brown globules of the venous blood take a vermilion colour from contact with the oxygen, and charged with oxygen, the blood penetrates into the radicles of the pulmonary veins. obeying the original impulse. the *vis a tergo*, as in the general venous system, but with greater quickness. It is now carried back to the left auricle, which immediately transmits it to the ventricle. where its circular course ends, only to commence again immediately. The circulation may be divided into two simultaneous periods, or, as has been already stated. the imaginary circle through which the blood passes is composed of two unequal segments described by the fluid column. The



Fig. 28. — Imaginary diagram of the course of the blood in the circulation.

A. *Course of the venous blood.*
B. *Course of the arterial blood.*

upper segment indicates the pulmonary or lesser circulation, the lower the general or systemic circulation.

Influences which retard or accelerate the beating of the heart.—In an adult in a normal condition, the heart beats about sixty times a minute, and the pulse consequently indicates the same number of pulsations, but diverse causes may augment or diminish the frequency of these movements. They become more frequent during digestion, and under the influence of alcohol, coffee, or other excitants; abstinence, on the contrary, retards them. Intellectual labour also accelerates the action of the heart, but the heart is calmer during sleep, and shares in a measure the repose of the other organs. An unlooked for sight, a word striking the ear, or a thought crossing the mind, will cause strong and rapid pulsations. Eristratus discovered the cause of the malady which threatened the life of Antiochus, by placing his hand on the heart of the young prince at the moment that Stratonicea appeared before him. The pulse is accelerated also by muscular exercise, and by violent efforts. But in this case the cause is complex, for the respiration is also more frequent, and this function is one of those which have most influence on the circulation. In ordinary breathing, each inspiration gives more force to the blood in the arteries, and if the respiration becomes more hurried it is recognizable in the pulse. If, on the contrary, respiration is suspended or imperfect, the circulation is retarded, and the pulse beats with less force; in a word, in most physiological conditions there is a constant relation between the respiratory movements and the beating of the heart. The alternate expansion and contraction of the walls of the chest are therefore one of the principal causes which affect the circulation, by facilitating the afflux of blood to the thoracic cavity and insuring its expulsion from it.

The pressure of the atmosphere also influences the beating of the heart, but only under certain conditions. It is not uncommon to find in the high valleys among the Alps men whose pulse beats between fifty and sixty times a minute—this infrequency is perhaps more common among mountaineers who live at an altitude of 3280 feet or more, than in less elevated

countries. We may consider therefore that the altitude has no influence upon persons who have long lived at a given level. But if we rise rapidly to a great height, the pulse quickens very sensibly. Aerostatic ascensions and mountain journeys furnish the proof of this. It is not to locomotion or to muscular effort that this quickening of the pulse can be attributed in the aeronaut or the traveller on horseback, but it is chiefly due to the greater frequency of respiration in an atmosphere of lesser density. The diminution of the pressure of the atmosphere conduces also to the same effect by relaxing the vessels; but the fall in temperature in proportion to the rise in elevation seems to neutralize this last effect by the contraction of the tissues which it induces. (See *Respiration*, p. 99.)

The establishment of the fact, that an increase in the pressure of the atmosphere diminishes the frequency of the pulse is due to the observations of Pravaz and Tabarié. Both these authors state that the pulse falls to fifty and even to forty-five pulsations per minute when the subjects are placed in an apparatus for compressing air, and the pressure is increased to that of two atmospheres and over. Results entirely contrary were observed by M. François in the tubes containing compressed air which he used in building the bridge at Kehl in 1860. This physician observed that the pulse invariably quickened in the labourers employed upon this work under a pressure of about two atmospheres. Other observations by M. Hermel establish the fact that the pulse is sometimes retarded, and sometimes quickened in compressed air to one hundred and fifty in a minute. The phenomena observed in men who work in compressed air seem to be due to complex causes, among which we must note the vitiation of the air from deficient renewal.

We shall not here discuss the numerous causes which may, in pathological conditions, influence the circulation.

CHAPTER X.

Nervous system.—Cerebro-spinal nervous centre.—Cerebrum.—Cerebellum.—Isthmus of the encephalon.—Medulla oblongata.—Spinal cord.—Membranes; dura mater, arachnoid, pia mater.—Nerves; cranial nerves, spinal nerves, great sympathetic.—Functions of the nervous system: functions of the spinal nerves of motion and of sensation: function of the cranial nerves; functions of the spinal marrow.—Functions of the encephalon: medulla oblongata, pons Varolii, peduncles of the cerebrum and cerebellum, corpora quadrigemina, pineal gland, optic thalami, cerebrum and cerebellum.—Functions of the great sympathetic.—Reflex power.—Nerve force.—Memory.

The *nervous system* comprises the cerebrum and cerebellum, the spinal cord, and the nerves. It is divided into two portions, the one central, and the other external or peripheric. The first has received the name of the *cerebro-spinal nervous centre*, because it is constituted by the organs which form the encephalon and by the spinal cord. The second is the whole of the nerves proper. Starting from the nervous centre, of which they are the expansion, they are distributed to the whole body. They transmit motive or functional impulses from the nervous centre to every part of the organism; and the impressions of sensibility from the periphery, that is to say from the different points of the body to the nervous centre.

The *cerebro-spinal nervous centre* appears in the form of a soft pulpy symmetrical trunk. Its upper portion is an oval enlargement contained within the cranium, and is called the *encephalon* or brain. The lower portion is elongated on leaving the cranium in the form of a spindle—it is the spinal marrow, and is contained in the vertebral canal.

Brain.—This is the term commonly applied to all the

parts of the encephalon, which are the brain proper, or *cerebrum;* the *cerebellum*, or little brain; the *isthmus of the encephalon*, or the attachment which joins the different parts together; and the bulb of the spinal cord, or *medulla oblongata.*

The brain occupies nearly all the cavity of the cranium, which fits it like a mould. It is oval in form, flattened on its inferior surface, which rests on the base or floor of the skull; its anterior or frontal extremity is smaller than the posterior. Its greatest transverse diameter is the space between the temporal fossæ. It is divided in the median line by the great fissure running from behind forward vertically through part of its depth into two portions, called the *hemispheres of the brain.* This division is complete in front, at the back and on the top, but the two parts are united at the middle and lower third by the corpus callosum, the peduncles, and some other parts situated in the middle line.

A lateral fissure, called the *fis-*

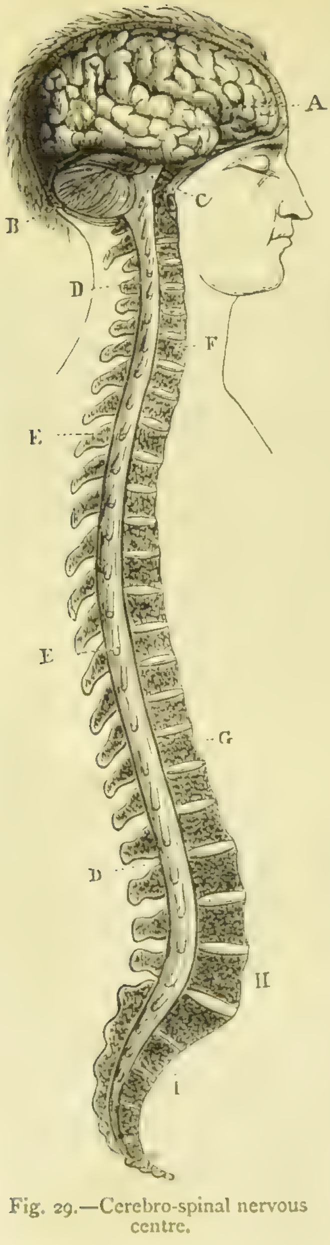


Fig. 29.—Cerebro-spinal nervous centre.

A. *Cerebrum—or brain proper.*
B. *Cerebellum—lesser brain.*
C. *Pons Varolii.*
D, D. *Spinal marrow, showing the origin of the spinal nerves.*
E, E. *Spinous processes of the vertebræ.*
F. *Seventh cervical vertebra.*
G. *Twelfth dorsal vertebra.*
H. *Fifth lumbar vertebra.*
I. *Sacrum.*



Fig. 30.—Nervous System.

sure of Sylvius, divides each hemisphere obliquely into two lobes, the *anterior* and *posterior*.

The surface of the hemispheres is broken with deep irregular *sulci* or furrows, which define the oblong rounded winding ridges, themselves subdivided by secondary furrows, and called, from their analogy to the windings of the smaller

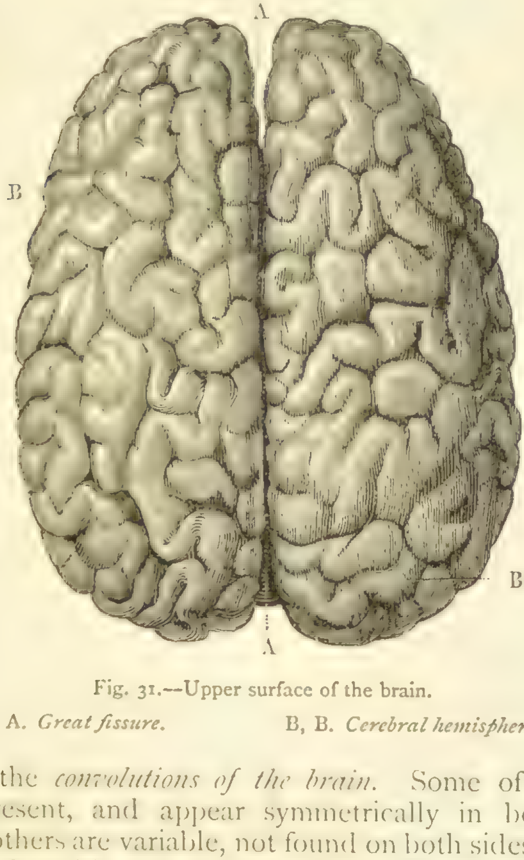


Fig. 31.—Upper surface of the brain.

A, A. *Great fissure.* B, B. *Cerebral hemispheres.*

intestine, the *convolutions of the brain.* Some of these are always present, and appear symmetrically in both hemispheres; others are variable, not found on both sides, differing in length, breadth, and in projection. These convolutions cover the external, superior, and inferior surfaces of both hemispheres, and are continued also on their internal surface the whole length of the great fissure, and of the fissure of Sylvius.

The lower surface or base of the brain presents an extremely complicated relief. In front, and on the sides, there are numerous convolutions. Towards the centre we find,

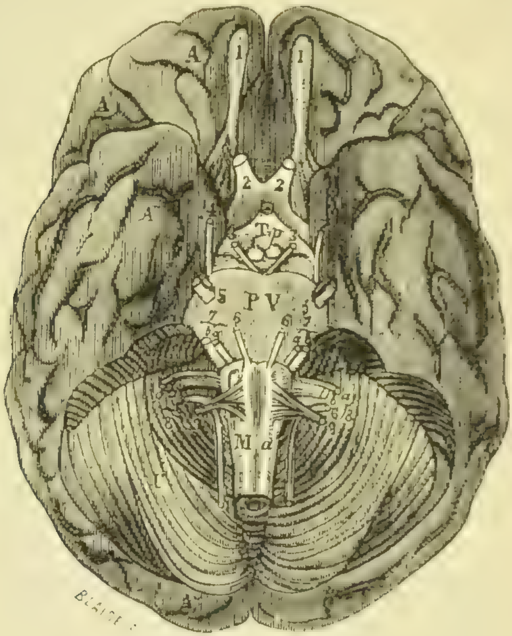


Fig. 32.—Lower surface of the brain.

A. *Anterior lobe.*
A′. *Fissure of Sylvius.*
A″. *Middle lobe.*
A‴. *Posterior lobe.*
C. *Cerebellum, or little brain.*
M*a*. *Medulla oblongata.*
PV. *Pons Varolii.*
T*p*. *The pituitary body.*
1-1. *First pair, or olfactory nerves.*
2-2. *Second pair, or optic nerves.*
3-3. *Third pair, or common motor nerves of the eye.*
4-4. *Fourth pair, or pathetic nerves.*
5-5. *Fifth pair, or trigeminal.*
6-6. *Sixth pair, or abducent nerves of the eye.*
7-7. *Seventh pair—a, Facial nerve.*
b, Auditory nerve.
8-8. *Eighth pair—a, Glosso-pharyngeal nerve.*
b, Pneumo-gastric nerve.
c, Spinal-accessory nerve.
9-9. *Ninth pair, or hypoglossal nerves.*

among other important details, the *olfactory nerves* on each side of the great fissure; the *chiasma*, or crossing of the optic nerves; the *pituitary body;* the *tuber cinereum*, or ash-coloured body; the *corpora mammillaria*, or mammillar bodies: and the

peduncles of the brain, which are, as it were, the roots of that organ uniting it to the other parts of the encephalon; the *pons Varolii*, or annular protuberance; the *medulla oblongata;* and the origins of the cranial nerves.

The brain, as well as all the divisions of the cerebro-spinal nervous centre, is composed of two distinct substances: the *gray* or *cortical* substance, the first on account of its colour, and the second because it is on the surface of the brain, like a *bark* (cortex); and the *white substance*, which is everywhere completely surrounded by the gray.

The gray substance is pulpy and less consistent than the white. It is disposed around the principal organs of the encephalon in a superficial layer, and enters into their substance in masses varying in form and volume. The white substance is filamentous in texture, and exhibits, according to the region, bundles, cords, or layers, composed of slender fibres, which are alike in the nervous centres and in all the nerves of the body. The white greatly exceeds the gray substance in total amount.

On laying open the brain we find it is composed of a central nucleus—or knot—unique and symmetrical, a sort of terminal enlargement of the nervous axis, and of two hemispheres united by this central portion, of which they are, as it were, a sort of double expansion. This central nucleus comprises parts very complicated in their structure and in their relative positions. The principal ones are the *thalamus opticus* or optic bed, the *corpora striata* or striated bodies, and the *corpus callosum* or hard body. All these subdivisions of the cerebral centre are united to each other, to the peduncles, and to the hemispheres. Thus the corpus callosum, which serves as an envelope of the cerebral centre, receives fibres from the peduncles and from the optic bed, prolongs its edges into the substance of the hemispheres, between which it is, as already stated, the principal means of union.

In the substance of the cerebral centre there are three cavities, called the *ventricles of the brain;* two are *lateral*, and the third or *middle* is placed on the median line; they communicate with each other, and are bathed with a serous fluid analogous to that which lubricates the spinal cord. On

the median line and behind the posterior commissure of the middle ventricle is a little body nearly conical, which anatomists have named the *pineal gland* or *conarium*, from its resemblance to a pine-cone.

A mass of white substance forms the central portion of

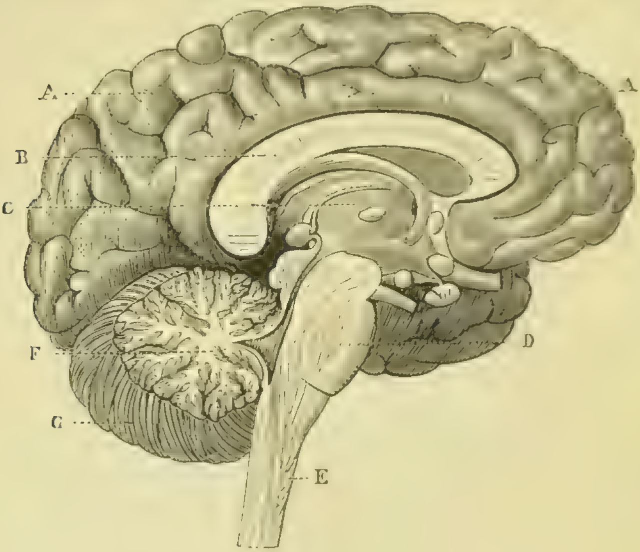


Fig. 33.—Section of the encephalon in the median line.

A. *Plane of the great fissure.*
B. *Corpus callosum.*
C. *Optic bed.*
D. *Pons Varolii, under which is seen the medulla oblongata.*
E. *Spinal cord continued from the medulla oblongata.*
F. *Section of cerebellum, showing the "tree of life."*
G. *Left hemisphere of the cerebellum.*

both hemispheres, and this is covered over in every part by the gray or cortical substance.

The brain is composed then, essentially, of a central nucleus, and two great lobes or hemispheres. The several parts of this nucleus differ in their texture, in the proportion of the gray and white substances, and in the disposition of these two substances in their tissues; but they all present fibres which are common to all, which penetrate and unite them before extending to the two hemispheres.

The mass of the entire encephalon is proportionally greater

in some species of animals, but none approaches man in the size of the brain proper. If man holds the first rank in creation, he owes his position to this admirable instrument of the soul, to this mysterious medium between the external world and the thinking being.

The volume of the brain is considerable from the first stages of existence, and larger in proportion in the newborn infant than in the adult. It is independent of sex and of the size of individuals. The weight of the brain in the adult varies, according to Cruveilhier, from 35 oz. to 52 oz.

The brain is symmetrical, but less constantly so than some other portions of the nervous centre, and there is often a notable disproportion between the two hemispheres without there having been any indication whatever of it during life. This want of symmetry was very marked in the brain of Bichat, and this is a striking proof that such a conformation does not necessarily have an unfavourable influence on the intellectual faculties, as was thought by this illustrious anatomist.

The cerebellum or *little brain* lies in the inferior occipital fossæ, that is to say, in the posterior and inferior portion of the cranium, and it is covered by the posterior lobes of the cerebrum. It is an ellipsoid in form, flattened from the top downward, with its large extremity behind, and its greater diameter transverse. It is symmetrical, and is composed of a middle lobe and two lateral lobes or hemispheres.

On the upper surface of the cerebellum is a protuberance, extending from the front backwards; it is formed by the middle lobe, and named from its peculiar appearance the *superior vermiform process*. The lateral lobes form an inclined plane on either side.

The lower surface fits into the occipital fossæ, and forms two rounded lobes separated by a furrow, which widens in front to receive the spinal bulb. About the middle of it is seen the *inferior vermiform process*, the lower surface of the middle lobe which unites the two hemispheres.

The whole surface of the cerebellum is furrowed with curved and projecting lines, which give it a wrinkled appear-

ance (fig. 32, p. 124). These lines or folds are all of about the same width, and are parallel through a portion of their course, and then they form acute angles, and are collected in fascicles, which point transversely downward or backward, and divide the hemispheres into *segments*, which are divided and subdivided into layers.

The cerebellum is composed, like the cerebrum, of white and gray substance, with the addition of a yellowish substance interposed in layers between the two others. Each hemisphere is formed of a central nucleus, around which the segments develop themselves. The layers of these segments are in juxtaposition like the leaves of a book; the white substance is in the centre; then comes a layer of the yellow matter, and over these the gray substance. If we make a vertical section of the cerebellum, the alternating layers of the three substances of which it is composed are seen forming a series of ramifications which spring from a common trunk: this has been named the *arbor vitæ* or *tree of life* (fig. 33, p. 126). At the nucleus or knot, the *peduncles* of the cerebellum terminate; they are three in number on either side, and serve to attach it to the other parts of the encephalon. Near the point where these different parts unite, there is a cavity which is partly circumscribed by the peduncles of the cerebellum; this is called the *fourth ventricle*, or ventricle of the cerebellum. It communicates with the third ventricle of the cerebrum by the *canal of Sylvius*.

Isthmus of the encephalon.—This is the term applied to that portion of the encephalic mass which unites the cerebrum, cerebellum, and the spinal bulb. It is the point of union of the three great divisions of the nervous centre. It comprises the pons Varolii, the peduncles of the cerebrum and cerebellum, the corpora quadrigemina, and the valve of Vieussens.

At the base of the encephalon there is a convex projection which surrounds the peduncles of the cerebrum and cerebellum like a large ring, and which covers the expansions of the spinal bulb toward these peduncles like a bridge. This is the *pons Varolii*, or bridge of Varolius. This projection is the centre of convergence or of emergence of the nervous fascicles or bundles which it seems to cover. It is joined to

the bulb behind, and in front to the peduncles of the cerebrum, and on the sides to the peduncles of the cerebellum. Its inferior surface, which rests on the basilar apophysis of the occiput, shows fibres running transversely. It is grooved along the median line, and is perfectly symmetrical.

On its upper face there are four mammillar projections; these are the *corpora quadrigemina.* Behind these, and between the superior peduncles of the cerebellum, stretches a thin layer of nerve substance, which has been called the *valve of Vieussens*, and which forms part of the boundaries of the fourth ventricle.

The bulb of the spinal cord or medulla oblongata.—This is the term applied to the enlargement of the upper extremity of the spinal cord. Pointing upward and forward, its anterior surface corresponds to the basilar groove of the occiput; posteriorly it rests in a depression of the cerebellum. Although it is within the cranium, the bulb should be studied at the same time as the spinal marrow, of which it forms a part.

Spinal cord.—This name is applied to the spinal portion of the nervous centre. It is a nervous stem, white, cylindrical, and symmetrical, and lies in, but does not completely fill, the vertebral canal; it is held in place by the *denticulated ligament* at each side. It is united with the encephalon by the medulla oblongata. Terminating in a point at its lower extremity, it rapidly increases in diameter, and forms the lumbar enlargement, so called from the region which it occupies; in the dorsal region it diminishes in size; augmenting anew as it approaches the neck, so as to form the cervical enlargement, it shrinks again about the middle of the cervical region, and then enlarges a third time at its superior extremity, and forms the *medulla oblongata.* The spinal marrow is marked in front and behind, throughout its entire length, by a fissure or *median furrow*, which divides it into two distinct halves, excepting a layer of white substance, which unites both the two fissures and the medullary fascicles to right and left. This layer, sprinkled with holes, designed to give passage to vessels, is the *perforated commissure.*

The anterior median furrow is covered at the top by the interlacing of the nervous fascicles which run obliquely from

one-half of the spinal marrow to the other, and of which we shall speak presently. The posterior furrow, like the anterior, disappears insensibly toward the inferior extremity of the spinal cord; at its upper extremity it opens at an acute angle where the medulla oblongata commences. Its form resembles the point of a pen—hence the name *calamus scriptorius* which has been given to this part of the medulla oblongata.

Each half of the spinal cord, separated from the other by the fissures indicated above, is composed of two cords or bundles; one, the posterior, giving origin to the posterior roots of the nerves, and the other, the anterior, to the anterior roots. These cords are attached to, and are continuations of, the pyramids of the medulla oblongata.

This latter is marked in front by the median furrow which extends beyond the interlacing of the fibres, of which mention has been made; on each side of this furrow there is an oblong elevation, these are the *anterior pyramids:* outside of which are two projections still more marked, called *olives* or the *olivary bodies.* Laterally there is a depression, grayish in colour, in which terminate the posterior roots of the spinal nerves; behind this we find a bundle of distinct fibres, the *restiform* or cord-shaped bodies; and lastly, outside of these bodies are the *posterior pyramids*, defining the calamus scriptorius on either side. The cerebellum, as we have already seen, covers the posterior surface of the bulb, to which it is united by the restiform bodies or *inferior peduncles* of the cerebellum, and which contribute with the cavity of the *calamus scriptorius* to form the fourth ventricle.

The anterior pyramids terminate by the interlacing of their nervous fascicles, and this interlacement may be considered as the lower boundary of the medulla oblongata. These pyramids are contracted at the apex and at the base, and are inserted into the pons Varolii by a sort of neck or contraction.

The anterior and posterior roots of the spinal nerves form two parallel lines on the sides of the spinal marrow. The roots spring from the spinal cord, but it cannot be anatomically demonstrated that their fibres return to it beyond the point where they originate and where they constitute by

their reunion the medullary fascicles. Opinions are not fixed on the mode by which union is effected between the nervous roots and the spinal cord, and we confine ourselves to the simple statement that the cord appears to consist of a greater number of nervous fibres than the nerves which spring from it.

The isthmus of the encephalon is formed by the expansion of the superior portion of the spinal cord; it is the central point of the greater and lesser brain, of which the hemispheres of the cerebrum and cerebellum are but the terminal developments.

Meninges or membranes.—The three membranes, placed one above the other, which line the cranium and the vertebral canal, which envelop the encephalon and the spinal cord, and extend to all their inequalities, are designated by this term. They are divided into the *dura mater*, the *arachnoid*, and the *pia mater*. The name *mater*, which is given to the external and internal meninges, appears to have been derived from the Arabs, who thus designated the covering of any body whatever.

The *dura mater* is a resistant, fibrous membrane, which lines the cavity of the skull and of the spinal canal. It adheres very slightly to the walls of this canal, but more strongly to the arch of the skull, and closely to its base. The *arachnoid* and the *pia mater* are interposed between the dura mater and the nervous centre. It is separated from the spinal cord by a space filled with the fluid peculiar to the spinal column; but it is, on the contrary, directly in contact with the encephalon, some portions of which it holds in place.

On the median line of the cranial arch is a triangular canal, circumscribed by the dura mater, called the *superior longitudinal sinus*, which performs the functions of a large vein. Below this sinus it forms a fold or vertical partition, which is called the *falx cerebri* (*falx*, a sickle), which descending into the great fissure, separates the cerebral hemispheres. In its lower border is the *inferior longitudinal sinus*. Between the posterior lobes of the cerebrum and the cerebellum the dura mater covers the latter with the *tentorium* or tent of the

cerebellum, which isolates it from the cerebral lobes. It also forms the *falx cerebelli*, which springs from the base of the skull between the two hemispheres of the lesser brain; and, lastly, it extends beyond the cranium, and furnishes the covering of the optic nerve, and the periosteum of the cavity of the orbit.

These folds and partitions formed by the dura mater around and between the organs of the encephalon, serve to maintain the different parts in place, to prevent their collision in shocks received on the body, and to prevent the parts from falling upon each other in certain positions; as, for instance, in lying on one side the falx cerebri prevents the weight of one hemisphere from resting on or compressing the other. The disposition of the *sinuses* of the dura mater is not less remarkable; they are, as already stated, venous canals with inextensible walls, through which the circulation is easy, and in no danger from obstruction or suspension; and when there is an afflux of blood it cannot compress the brain, as would be the case if the sinuses were replaced by veins with extensible walls.

Arachnoid.—This membrane has been compared to a spider's web from its extreme tenuity, and from this it derives its name. It is a serous membrane, and lines the dura mater throughout its whole extent. Like the other serous membranes, it is a sac without an opening, the walls of which, placed back to back, secrete a fluid. It adheres very strongly, by its external wall, to the dura mater, to which it moulds itself, and which it accompanies throughout its whole extent. Its internal wall is united to the pia mater, which separates it from the nervous substance at many points. This union is so intimate that many have thought the arachnoid has no existence except where it is detached from the pia mater, as at the level of the fissure of Sylvius, and in the cerebral sinuses, &c. In fact, the arachnoid does not enter those intervals where the dura mater does not penetrate, but is strictly confined to it. At these intervals there is a cavity between the serous membrane and the nervous centre which it surrounds, but does not touch, as is well illustrated by the spinal cord.

All the cavities formed by the arachnoid are filled with a serous fluid called the *sub-arachnoid* or *cerebro-spinal fluid.* The ventricles of the brain also contain, as has been stated, a quantity of serous fluid. The use of this fluid seems to be to protect the organs against the effect of blows and shocks. The brain and spinal cord being, as it were, suspended in the arachnoid, are held in place in the gentlest possible manner by the sub-arachnoid fluid, and by that in the ventricles which moistens the surfaces and prevents all friction.

Pia mater.—This is the name given to the membrane which immediately surrounds the nervous centre. It is a vascular net-work of extreme delicacy and fineness of texture, and may be considered as the nutritive membrane of the cerebro-spinal organs. In its tissue, the arteries running to the brain are ramified with infinite minuteness, and inosculate with the radicles of the veins which spring from it. It follows closely all the cerebral convolutions; penetrates the furrows, and into the ventricles, and covers even the thin layers of the cerebellum. It becomes denser and more fibrous around the spinal cord, of which it forms the *neurilemma* or envelope, as well as at the origin of the nerves.

To recapitulate, the greater and lesser brain, and the spinal cord, contained in the skull and spinal canal inclosed in three superposed membranes, are united by a common centre, the isthmus of the encephalon. Nerves spring from the brain and spinal cord.

Nerves.—This is the name given to white or grayish threads which are attached by one extremity to the cerebro-spinal nervous centre, and at the other are distributed to the organs. The nerves are composed of very fine filaments, united at the point at which they spring from the nervous centre in bundles called the *roots of the nerves;* these roots unite and form the trunks which ramify and disappear, as it were, in the tissues of the body. A sheath of cellular tissue called *neurilemma* or *perineurium*, envelops the nerves, and penetrates between the *fibres* formed by the union of the nerve-tubes spoken of in treating of the tissues. The ramifications of the nerves unite and seem to be confounded at certain points where they form a very complicated net-work, which is

termed a *plexus;* but this union is effected solely by the neurilemma. One nerve-fibre—properly speaking—never is confounded with another. It runs without interruption, and always distinct, through the most intricate net-work, from the nervous centre to the organ which it serves. From the analogy with the union of the blood-vessels, we speak of the anastomosis of the nerves, and we shall soon see that if the union of the vessels with each other is an essential condition of the circulation of the blood, the distinct and absolute independence of the nerves, even to their minutest ramifications, is no less necessary to the integrity of the nervous functions. We may therefore compare the union of the nerves by juxtaposition during their course to a bundle of electric wires which, though united, are always distinct, because of their isolating covering. The isolating covering of the nerves is the neurilemma.

M. Sappey has recently described, under the name of the *nervi nervorum*, or nerves of the nerves, the filaments which run to the neurilemma, and which stand in precisely the same relation to the nerves that the nerves themselves do to the entire organism.

There are two orders of nerves: the one, under the influence of the will, causes motion in the organs; these are the *nerves of animal life:* the other presides over the functions of the viscera without our consciousness, and without any effort of will; these are the *nerves of organic life.* The first are *cranial* or *spinal* nerves, and spring directly from the nervous centres, they are white and generally of a resistant texture: the second, *ganglionic* or *visceral* nerves, although connected with the nervous centre, form a system apart, which is called the *great sympathetic.* These nerves are for the most part soft, and of a grayish colour.

Cranial and *spinal nerves.*—These nerves are all disposed in *twos*, and form a series of *pairs* to the number of forty, of which nine pairs are cranial or cerebral, and thirty-one pairs are spinal.

The cranial nerves are classed as follows:—

1st pair. *Olfactory* nerves, which are ramified in the organ of smell.

2d pair. *Optic* nerves, which preside over the organs of sight. Its terminal expansion forms the retina.

3d pair. The *common oculo-motor* nerves, which are distributed to most of the muscles which move the eyeball.

4th pair. *Pathetic* nerves, so called, because they give the power of motion to the great oblique muscle, the action of which, upon the eyeball, is one of the principal elements in the expression of the face.

5th pair. The *trigeminal* or *trifacial* nerve forms on either side three nerves, the *ophthalmic* and the *superior* and *inferior maxillary;* they are distributed over the face, and to the organs which constitute it.

6th pair. The *external oculo-motor* nerves. These go to the external straight muscle of each eyeball. The

7th pair is divided into the *hard portion* or *facial* nerve, which goes to the face, and the *soft portion* or *auditory* nerve, which goes to the internal ear. The

8th pair is divided into three branches: 1. the *glosso-pharyngeal*, the nerve of taste, running to the tongue and pharynx, and furnishing branches to several muscles of the neck, to the tonsils, &c. 2. The *pneumo-gastric* nerve, which branches out to the cervical region, to the pharynx, the larynx, the lungs, and the stomach. 3. The *spinal accessory* of Willis, which sends branches to several muscles of the neck, to the pharynx, and to the larynx.

9th pair. The *great hypoglossal* nerves, which give movement to the tongue.

The *spinal* nerves form eight cervical pairs, twelve dorsal, five lumbar, and six sacral. They all spring from the spinal cord in two bundles of *roots*, called the *anterior* and *posterior* roots, according to the portion of the cord from which they emerge. These roots are enveloped in a membranous sheath, and unite to form the trunk of the nerve at a point more or less distant from their origin, according to the region from which they proceed. The roots of the lumbar and sacral nerves form a bundle of independent cords in the inferior portion of the spinal canal, which, from their peculiar disposition, has been named the *cauda equina* or *horse-tail.*

On a level with the openings through which the nerves

pass from the spinal canal, the posterior roots form a ganglion on each side to which the anterior roots unite themselves, and from which the nerve is distributed to the organism by three classes of spinal branches, *anterior*, *posterior*, and *ganglionic;* the latter unite with the great sympathetic.

The first four pairs of cervical nerves form by the contiguity of their branches the *cervical plexus;* the ramifications of which distribute themselves to the surface, and to the deep portions of the neck, to the outside of the head, to the shoulder, and to the upper portion of the back.

The last four pairs constitute the *brachial plexus*, which, after furnishing numerous branches to the shoulder and back, go to the arm as the *brachio-cutaneous*, *musculo-cutaneous*, *median*, *radial*, and *ulnar* nerves.

The twelve pairs of dorsal or intercostal nerves, as well as the five pairs of lumbar nerves, are ramified in the walls of the thorax and abdomen, and in the muscles of the back and loins. The *lumbar plexus* furnishes, among other principal branches, the *crural nerve*, which ramifies into the *musculo-cutaneous* of the leg, and the *external* and *internal saphenous* nerves, &c.

The six pairs of sacral nerves are distributed to the pelvis and to the lower limbs. The first four pairs with the last lumbar pair form the *sacral plexus*, the principal terminal branch of which is the *sciatic* nerve. This is the largest nerve in the body; it descends through the posterior portion of the thigh, to the muscles of which it furnishes several branches; and a little above the knee it divides into two trunks — the *internal popliteal* or *tibial*, and the *external* or *peroneal*, which distribute themselves by numerous ramifications to the muscles of the leg and foot.

The *great sympathetic.*—The nervous apparatus designated by this name consists of a double cord placed on either side of the spinal column, the whole length of the neck, and in the interior of the thoracic and abdominal cavities. It is, as has already been stated, the nervous system of organic, vegetative, or nutritive life. Extending from the first cervical vertebra to the last vertebra of the sacrum, the great sympathetic enlarges at the level of each vertebra, and forms

nervous ganglia, which communicate by external filaments with all the cranial or spinal pairs, and constitute by their internal filaments all the visceral nerves. This string of ganglia gives the great sympathetic the name of the *ganglionic nervous system.*

The great sympathetic forms the *pharyngeal*, the *cardiac*, the *solar* or *cœliac* and the *hypogastric* plexuses. These are the nervous centres of organic life.

The nerves emanating from the great sympathetic surround the arteries like a sheath, and penetrate with them into the organs. Some of these nerves, as has already been stated, are soft and of a grayish colour, and others are white and firm.

Functions of the nervous system.—The nervous system is the seat of intelligence, of sensation, and of motion; it is the centre of action for the organism, and it presides over all the phenomena which together constitute *life.* Its spinal and superficial portions—the cord and the nerves—take part only in the functions of sensation, of motion, and of organic life: but the encephalon contributes at once to the material and mental functions.

Observers have succeeded in distinguishing in the nerves and spinal cord the apparatus which is specially devoted to sensation, from that which presides over motion. But the knowledge which we have attained concerning the special functions of the different parts of the encephalon is as yet very limited, and for the most part hypothetical. Comparative physiology teaches us that some portions are extremely sensitive and irritable, while others are not affected by external agents. The medulla oblongata, the pons Varolii, and quadrigeminal bodies, are most allied to the spinal cord, and anatomy can follow thither the medullary fascicles endowed with sensibility, but beyond them these same fascicles become insensible in the greater and lesser brain, the optic beds, &c. It appears that after having transmitted the external impression, they change their nature, becoming an integral portion of the organ in which the sensation is produced, and submitted to the apprehension of the intelligence. We are no less embarrassed if we attempt to specify the portions of

the encephalon which preside over motion. As for the seat of the intellectual faculties, we cannot doubt that it is situated in the encephalon, but science possesses no exact data regarding the part played by the different organs contained in the cranial cavity in the elaboration of thought, and the soul cannot perceive the mysterious tie which unites it with these organs.

The nervous system, which gives motion and sensibility to every part of the body, is itself absolutely dependent on the circulation. It determines and regulates its progress by exciting the action of the heart, but it must itself be excited by the afflux of blood which the arteries bring to it; and just as the heart slackens or even stops its action under the influence of certain impressions, the functions of the brain, spinal cord, and nerves are inevitably suspended when the blood does not come to awaken the nervous energy. Any impediment to circulation of the blood induces paralysis, more or less complete, in the parts beyond the obstacle, and no sooner does the nourishing fluid stop its motion, or even slacken, in its course toward the brain, than syncope or fainting supervenes; that is to say, the functions of the encephalon are weakened or cease altogether.

In giving a summary description of the nervous system, we have proceeded from centre to circumference, but in describing the nervous functions the reverse course seems preferable.

Functions of the sensitive and motor spinal nerves.—Sensation may be destroyed in a portion of the body while it still possesses the power of motion, and conversely a limb may lose the power of motion and still remain sensitive to external impressions. This independence of motion and of sensation revealed to the physiologists of antiquity the existence of two orders of nerves, one sensitive the other motor. Boerhaave and other modern anatomists accepted these doctrines, on which Lamarck based and promulgated theories nearly approaching the truth; but Sir Charles Bell was the first to distinguish, by actual experiment, the nerves of sensation from those of motion, and to show that they sprang from two distinct portions of the spinal cord.

The anterior fascicles of the cord and the anterior roots of the nerves which proceed from them are insensible, and produce muscular contraction. The posterior fascicles of the cord, and the posterior roots of the nerves, have no motor power, but they are sensitive. Each spinal nerve, formed by the union of the anterior and posterior roots, contains sensitive filaments and motor filaments placed side by side in its trunk and its ramifications. It follows, therefore, that these nerves and their subdivisions are *mixed;* as regards the composition of their fascicles, they are at once sensitive and motor. They are sensitive to mechanical irritation, and they excite muscular contraction under the influence of galvanism, for both these agents meet in the same nerve-filaments subject to their power. These filaments, separately considered, come from the centre to the periphery without division and without anastomosing, in the exact sense of the word, for what is called anastomosis of the nerves is a simple juxtaposition, proximity without exchange of their proper substance, and without intimate fusion.

It is to the continuity of the nervous filaments, and to their independence, that distinctness of tactile sensation and precision of motion is due. It is clear, therefore, that if two sensitive filaments should unite their proper substance, the impressions perceived by them previous to their union would be confounded, and would not be referred by the brain to distinct points. If, for example, two filaments running to the index and middle fingers, were united, instead of being simply placed side by side, at any point between the finger-tips and the brain, they would carry to the brain but one single sensation for both fingers, and it would be impossible to tell upon which one the impression had been made. The result would be the same if two filaments of a motor nerve running to these fingers were united, instead of isolated in their proper substance; the motor impulse would be transmitted to both fingers alike, and the brain could not move either expressly.

In persons who have suffered amputation, phenomena are produced which are explained by the fact that all the filaments of a nerve exist at its origin which are found at its

extremity. The man who has lost an arm or a leg, feels pains, which he refers not to the stump which remains, but to the hand or the foot which he has lost. It is the nervous filaments primitively destined to these parts which are the seat of the pain, and which now transmit it as coming from the organ to which they formerly gave sensibility. The same effect is produced when a piece of skin has been transplanted from the forehead to the nose by autoplasty; if the patient be touched on the nose he feels the impression on his forehead.

We shall see in treating of the senses, that tactile impressions may be distinct on the tips of the fingers, at a distance of one-fiftieth of an inch from each other; which implies that there are two filaments at this interval from each other, running directly to the brain, but we err if we reckon in this way the extent of nerve subdivision, for every point in the skin, however small, is sensitive to the touch. It is by innumerable ramifications, each of which contains at least one nervous filament, that the nerves terminate in the organs, those of motion to excite muscular contraction, and those of sensation to receive and transmit impressions.

Functions of the cranial nerves.—Like those which spring from the spinal cord, the nerves of the brain are divisible into motor and sensory nerves. Among these last some are endowed with a special sensibility, as the olfactory, the optic, and auditory nerves; the others transmit general sensations. Several of the cranial nerves are made up of filaments of different orders, and are formed by the union of nerves of general sensation, of special sensation, or of motion. Like the spinal nerves after the union of their roots, they form cords, mixed in their functions as a whole, but distinct in those of their several filaments. The analogy between the cranial and the spinal nerves is completed by the branches which go from the cranial nerves of sensation to the great sympathetic, and by the gray fibres which are seen near the origin of the cranial nerves, and also near the posterior roots of the spinal nerves. In the cranium the motor nerves emerge from the prolongation of the anterior fascicles of the cord in which the spinal motor nerves originate.

Functions of the spinal cord.—We have already seen that the anterior fascicles of the spinal cord are insensitive, and that they give motor power to the anterior roots of the nerve, while the posterior portions are sensitive, like the nerves which emerge from them. These properties of the medullary fascicles were for a long period disputed, but they have been clearly demonstrated by M. Longet's experiments. The spinal cord imparts to the nerves of the trunk and limbs the power of voluntary and respiratory motion. It is also the source of nervous energy in the action of the heart, and in the circulation of the blood, in the phenomena of nutrition and of secretion; lastly, it seems to have only an indirect influence on the production and maintenance of animal heat. When there is any lesion of one of the lateral halves of the cord, it is on the corresponding side of the body that motion and sensation are disturbed or destroyed. The action therefore of the spinal cord is *direct* on the organs to which it sends nerves, and not *crossed* like that of the encephalon.

Functions of the encephalon. Medulla oblongata.—The medulla is the central source and regulator of the respiratory movements. It is in a limited portion of this enlargement of the cord, near the origin of the eighth pair of nerves, that, as Flourens has demonstrated, the organ which he calls the *prime mover*, or *vital node*, of the respiratory mechanism has its seat. This organ, according to M. Longet, does not comprise all the substance of the bulb, but is only a fascicle, composed of gray substance between the pyramidal and restiform bodies. The medulla transmits impressions from the cord to the brain, and the impulse of the will from the brain to the cord; its anterior and posterior portions are prolongations of the corresponding medullary fascicles, and we may conclude therefore that they share their functions as they do their substance; and that the medulla by its anterior portion controls movement, and by its posterior portion sensation. In point of fact, all the nerves which spring from the anterior portion are sensitive, and from the posterior motor. The anterior fascicles of the medulla cross their fibres, and from this results a cross action on the motor nerves, which originate from these fascicles; the posterior

fascicles, on the contrary, do not cross each other, and their action is direct.

Pons Varolii.—The movements of locomotion are originated specially, according to M. Longet, in the pons Varolii. This portion of the encephalon has a cross action on motion. It is a centre of perception for tactile sensations, but nothing authorizes us to believe that it can appreciate sensation by itself alone, and without the aid of the cerebral lobes.

Peduncles of the brain.—These organs unite the greater and lesser brain to the isthmus of the encephalon, and to the spinal cord, and seem to be solely devoted to the transmission of motion and sensation. An injury to one of the middle peduncles of the cerebellum causes the body to turn on its axis; a phenomenon which has been variously explained by different writers.

Corpora quadrigemina, or quadrigeminal bodies.—These bodies take an essential part in vision, either by inducing the contractions of the iris, or in contributing to visual perceptions.

Pineal gland.—The hypothesis of Descartes has popularized, so to speak, this organ, whose functions are entirely unknown. The illustrious philosopher believes the pineal gland to be "the source from whence the most subtle parts of the blood, the spirits, flow to all parts in the brain, and are directed to a particular point, according as the gland is inclined one way or the other." This idea of Descartes has been parodied, by making the pineal gland the seat of the soul, from whence it directs the impulses of the brain by two nervous prolongations, called the "reins of the mind" (*habenæ animi*).

The optic beds.—In spite of the name which has been given them, these portions of the encephalon do not seem to have any appreciable action on the sense of vision; but they act upon the voluntary movements in such a manner that the influence of the right half is felt on the left, and *vice versa*: this is called cross action, which is caused, as already stated, by the crossing of the cerebral fibres. The optic beds seem to have no influence over the movements of the upper extremities, as has been thought by several physiologists.

It is unnecessary to enumerate the other portions of the encephalon, of which the functions are doubtful, or entirely unknown.

Cerebrum.—Observation has enabled physiologists to distinguish in the spinal cord and spinal nerves, and even in the cranial nerves, the sensitive and motor portions; and we must admit from the results of experiment in comparative anatomy, that certain regions of the encephalon are endowed with sensibility, while others are insensible; but we have not yet been able to recognize in the encephalic mass the central organs, which preside over sensation and over motion. Nothing authorizes us to think that the insensible portions of the brain do not take a part in the motor and sensatory functions, and we are still less able to point out in the encephalon the seat of intelligence. We see the intellectual faculties develop themselves in the child, at the same time with, and in proportion to, the development of the brain; and we know that these faculties continue imperfect, or changed, when the normal development of the organ is arrested, and when it suffers from certain lesions; but these facts, incontestable in principle, have no absolute application. The brain may be wounded, and even a portion of it may be destroyed, without any sensible change in the intellectual faculties; a man of genius may have an ill-developed brain, as Bichat, for example, whose cerebral lobes were not of equal volume. On the other hand we see the intellect clouded under the influence of alcohol, of certain poisonous substances, or an attack of fever, and no trace is left in the encephalon of the temporary disturbance; sleep produces an analogous effect; dreams are only a succession of false ideas, a real delirium which ceases on awaking. And, indeed, in the insane, science can in many cases prove nothing but their misfortune, of which no part of the brain suggests in the slightest degree the organic cause. Physiology, therefore, is very reserved in regard to the cerebral functions, and most of its theories concerning them are disputed and uncertain.

The cerebral lobes do not seem to be essentially necessary to the perception of sensitive impressions, general or special. Thus, pathological observation has established the fact, that

vision may be equally good in both eyes, although one hemisphere may be atrophied, or may have suffered, as from wounds, a great loss of substance. It is, on the contrary, exclusively in the cerebral lobes that the perception of sensations lies, and that the ideas are formed which these sensations create. It is also from the hemispheres that the impulse emanates, which results in voluntary motion. Some physiologists have referred this impulsion to the white, and others to the gray substance of the brain. Wherever may be the seat of the motor principle, we know that the brain exercises a cross action on the muscles; that is, the left hemisphere induces the movements of the right side, and the right hemisphere those of the left. But in certain cases the action is direct notwithstanding; this has been explained by an exceptional incompleteness of the crossing of the cerebral fibres. Physiologists have sought in vain to localize the source of motion in the brain, and the difference of opinion on this point does not permit us to consider it a settled question.

The encephalon controls the intellectual phenomena, and most authors consider the cerebral lobes the seat of the soul. In the superior animals the most complete development of the brain proper coincides, in fact, with the greatest degree of intelligence, and the proportions of the brain of man unite with his intellect in placing an immense interval between him and animals the most gifted in this respect. And lastly, the encephalon in idiots is specially characterized by atrophy of the cerebral lobes, of their convolutions, and of the gray or cortical substance. Several authors, from repeated observation of this latter fact, have considered the gray substance as the seat of the intellectual faculties.

We have already stated, in speaking of the skull, that Gall and his school have placed the intellectual faculties in the anterior lobes of the brain, the moral qualities or tendencies of the mind in the middle lobes, and the animal faculties or instinctive propensities in the posterior lobes. This doctrine seems to be the rational consequence of that which recognizes one portion of the encephalon as specially designed for the functions of the intellect; but if we admit the possible

existence in the brain of distinct and multiplied apparatus in the explanation of psychological phenomena, it is simply a hypothesis of which it is out of our power to furnish a single proof. It is objected, and with reason, to the phrenological theory, that it groups all the faculties in those portions of the brain which correspond to the arch of the skull, to the exclusion of those resting on its base; and besides, pathological anatomy is not in accord with the theory of Gall, and comparative anatomy does not permit its admission.

The cerebellum.—Among the various functions which physiologists have attributed to the cerebellum, one only has been generally admitted in latter times; that is the co ordination of movement. The repeated experiments of Flourens, confirmed by those of MM. Bouillaud and Longet, seem to prove that the injury or absence of the cerebellum causes a confusion in the movements similar to that induced by intoxication, and that this organ is, in fact, the regulator of motion. Still pathological anatomy does not agree in this respect with the experiments made upon animals. Perfect integrity of function, and especially of locomotion, has been observed in congenital absence of the cerebellum. A great number of observations made by M. Andral prove that the cerebellum may be diseased while movements do not cease to be coordinated. The recent investigations of M. Duchenne, of Boulogne, also contradict the theory of Flourens, and it is now perfectly well known that the greatest disorder may exist in the movements without the slightest indication of lesion in the cerebellum.

Functions of the great sympathetic.—The nervous apparatus designated by this name is formed, as we know, by the sensitive and motor filaments coming from the cranial nerves, or from the roots of the spinal nerves. That is, its ramifications are, at the same time, sensitive and motor. The movements excited by the great sympathetic are not under the influence of the will. The motor impulse springing from this system differs also from that which determines voluntary movements, in that it travels less rapidly. Experiments upon animals also prove that the ganglia and ramifications of the great sympathetic continue their functions some time after they

cease to be in communication with the nervous centre. The movements they induce are then executed under the influence of the nervous force pre-existing, and stored up in their substance. The great sympathetic gives motion and sensation to the machinery of organic life; it controls the nutritive functions, the circulation, the secretions, &c.

Reflex power.—Besides the voluntary movements which result from the transmission of impressions by the nerves of sensation, and from the perception of these impressions, others are produced in which the will has no part, and which result from the impulse directly reflected upon the motor nerves, without any sensation having necessarily taken place, or at least without our having any consciousness of it. These are called *reflex movements*, and the force which determines them, and is considered as peculiar to the nervous centre, is called *reflex power* or the *excito-motor* faculty. Several physiologists have considered the phenomena classed under the name of *recurrent sensibility* as belonging to this reflex action, but upon the origin of this sensibility authors are not agreed.

Lastly, there is another reflex action which gives rise to *sympathy*, that is the particular influence which certain organs exercise upon others, such as the sensation called setting the teeth on edge, produced by the grinding of metal against stone or glass, and the sneezing provoked by tickling the pituitary membrane, or by snuff, &c. (See *Movements*, p. 59.)

Nervous force.—The almost instantaneous transmission of sensation and the motor impulse, by the different parts of the nervous system, is one of the mysteries of the organism. This class of phenomena has been compared to those produced in nature by electricity or magnetism, and the question has been raised whether the nervous system is not under the influence of an imponderable fluid produced in its substance, or drawn from the same source as all the elements of animate matter. Various names, such as nervous fluid, nervous force, the active principle of the nerves, have been given to the agent whose hypothetical existence permits us to explain the nervous functions, as we explain the action of the galvanic pile or the movements of the magnetic needle. The admirable discovery of Galvani seemed to

prove the analogy, if not the identity, of the electric and nervous fluids. Naturalists and physicians have striven to establish by the aid of experiment, that electricity is developed in the nervous centres and circulates in the nerves. But up to the present time, the most delicate instruments in the hands of the most skilful observers have failed to detect in the nerves the slightest electric current, and nothing authorizes us to consider the nervous force as identical with electricity. May we not consider them as at least analogous? They may both be developed by friction, by chemical combinations, by heat, &c.; both are rapidly transmitted, and both cause an elevation of the temperature, and the composition or decomposition of certain products. But while it is true that motor impulses are transmitted with great speed, comparable to that of the electric fluid, the nervous system contributes only indirectly to produce animal heat, and nothing here suggests a current heating a metallic wire. In fact it is only by hypothesis that we assume the influence of nervous force on the chemical operations of life, otherwise than in giving activity to the organs intrusted with these operations. But we must, notwithstanding, admit a certain analogy between nervous phenomena and electrical phenomena. Further research will doubtless throw light upon this question, which is so eagerly studied, and which would perhaps have already been solved if we could compare the reactions of inert matter to the transformations of organized matter, and the phenomena which are purely physical with those in which life takes part.

The memory.—The Greeks made Mnemosyne the mother of the Muses, and for us, under a less poetical form, memory is the indispensable bond of union of the intellectual faculties.

The senses reveal to us the external world, the intellect apprehends the sensations, and rising from material notions to abstract conceptions, embraces all that man is permitted to learn or to know; but it is the memory which enables us to record, as in a book, facts and results, to compare and to judge, to express thought by language, and to share the thoughts of others. Without memory man would not recog-

nize the ties of blood, of friendship, or of gratitude; the past would have no existence for him, his life would only embrace the present moment, and would flow on like the period immediately succeeding birth. Deprived of experience, impelled by blind instinct, isolated in creation, he could not exist with organs which render necessary everything of which he would be deprived. We cannot therefore imagine the human race without memory, and in order to find an organization without this faculty we must descend to the lowest grades of animal life.

Memory is of a compound nature: partaking of body and of spirit, it is a reflection, an image of ourselves, since it carries us back to every moment that has impressed our lives. An exact and enthusiastic historian of the facts which she recounts to us, she seems to add to our existence the hours already passed, but as she approaches epochs she rudely makes us sensible of the flight of time. It may be happiness that makes us recall hours of pleasure, or in misfortune we may remember them with that pain of which the poet sings. She shows us the faces of all who have had a part in our existence, sometimes an isolated portrait, and at others a crowded gallery; a minute object, a plant, a rock, or the grandest scenes in nature; a word, or the entire work of a writer; a fact, or the history of a people. She carries us back in an instant to the most vivid impressions, or to the most abstract conceptions, whether of the senses or the intellect. In taking the form of sensation or of thought, she makes us traverse time and space with a swiftness of which nothing material can give us an idea; we might indeed say, that time and space have no existence for the memory, if she did not in surmounting them awaken the idea of the one and the other. Obeying the behests of the will, memory retraces a scientific doctrine as a whole and in detail, the nicest distinctions of the most violent dispute, the series of systems of philosophy, all, in a word, that science or the most profound erudition has been able to classify in the mind.

We find everywhere the records of extraordinary memories, great numbers of which come down to us from antiquity.

Mithridates spoke twenty-two languages or dialects according to Aulus Gellius, and forty according to Pliny. Scipio the Asiatic knew most of his legionaries by name; Julius Cæsar, Hortensius, Lucullus, Adrian, and many others, prove that a powerful memory is not incompatible with a superior mind. Pic de la Mirandole was a fresh example in the fifteenth century, as were also Leibnitz and Haller in the eighteenth. The last-mentioned cites a German, named Müller, who spoke twenty languages, and in our day we have Cardinal Mezzofanti, who spoke nearly fifty, exclusive of dialects, conversing with the pupils of the College of the Propaganda, who had come from every quarter of the globe.

It is related also that Scaliger learned Homer by heart in twenty-one days, and the other Greek poets in four months; and we are assured that Magliabecchi could dictate whole books after having read them once; and if some of these examples of prodigious memory are not verified, they are at least rendered very probable by those which are incontestable.

It was an extraordinary memory which enabled the young Sicilian shepherd, Mangiamele, to calculate mentally with such rapidity, that the members of the Academy of Sciences could scarcely follow him even by the aid of the most expeditious processes. But the very ordinary intellect of this young man proves that in his case memory was a faculty out of all proportion to the others, a circumstance often observed especially in children.

Memory is sometimes awakened by a sensation which carries us back to the time and place where such or a similar sensation was produced. This memory of the senses acts upon us with extraordinary power, it is one of the most effective means which writers possess of touching the human heart. Eneas wept on beholding a picture on the walls of Carthage, which recalled the misfortunes of his country. "*En Priamus*," Behold Priam! said he, addressing his companions in exile. Andromache watered with her tears the grassy mound she had consecrated to the memory of Hector on the banks of another Simois; and the Florentine

accent of Dante made the Ghibeline Farinata forget the tortures of hell.

In former times the musicians of the Swiss troops in the service of France were forbidden, under severe penalties, to play their national airs, and especially the "Ranz des Vaches," as it caused the soldiers to desert, or made them home-sick. Taste and smell are not less powerful in awakening memory, even after many years have passed.

The seat of memory has been vainly sought in the brain. Gall and several other physiologists have placed it in the anterior lobes, and the phrenological school assigns certain circumscribed portions to the memory of words, of places, of numbers, and of persons, &c. But this localization is not justified by observation, and it is no more required by the memory than by the other faculties. Indeed, the impossibility of attributing to the brain the projections which vary solely according to the dimensions of the frontal sinus, was one of the objections to the doctrine of Gall. It is remarkable, also, that contrary to the opinion of phrenologists, the greater or less prominence of the eye (that is, the greater or less depth of the orbit) bears no relation to the development of the memory. There is more foundation for the observation of particular aptitudes of memory, specially to retain words, facts, numbers, &c. We may go still further, if we observe the changes induced by disease, for in certain cases the memory fails to retain substantives, or verbs, or other classes of words only, while all others are retained without difficulty. We may therefore suppose that certain parts of the brain are devoted specially to each detail of the memory as to the other faculties, as to the sensation of every nervous filament which transmits a tactile impression from any point of the body. This almost infinitesimal division of the brain will not astonish us in view of analogous facts derived from observation, or which reason imposes upon us, although no material demonstration is possible; yet we must also admit that the brain, as an organ of apprehension, acts as a whole, and that if a distinct apparatus exists for the memory, its action is at once single and multiform, each of its parts receiving with equal aptitude the impression of the ideas which

are assigned to it. Is it not thus that the innumerable divisions of the retina perceive with equal distinctness degrees of light? and is it not rational to suppose that it is the same with the region of the brain, which receives the nervous filaments which spring from every portion of the retina?

Very feeble in the first stages of life, the memory is developed along with the cerebral convolutions, and the gray or cortical substance. It loses its facility as mature age succeeds to youth, and retains with more difficulty the facts confided to it in proportion as years accumulate. In the aged it retains the impressions acquired during the first half of life, though in some fortunately endowed organizations it continues to increase its stores. Cato learned Greek in his old age; and Baron Humboldt at fourscore embodied in his *Cosmos* the whole circle of the sciences, and their most recent discoveries.

CHAPTER XI.

Sense of sight.—Organ of vision.—Globe of the eye; sclerotic; cornea; choroid; ciliary ring; ciliary body; ciliary process; iris; pupil; uvea; pigment; retina; vitreous body; hyaloid membrane; crystalline; anterior and posterior chambers; aqueous humour.—Muscles of the eye.—Conjunctiva.—Eyelids, eyelashes.—Lachrymal apparatus.—Vision; functions of the retina, reversed images; functions of the iris; optic centre, visual angle, visual impressions, single or mixed, adaptation of the eye to distances, myopia, presbyopia; achromatism; single and double vision with two eyes, stereoscope; alternation in the action of the eyes; persistence of impressions on the retina; accidental images; irradiation; accidental aureola; Daltonism; apparent motion of objects.—Optic nerve.—Movements of the eye.—Extent of vision.

Organ of vision.—The visual apparatus consists of the globe of the eye and its appendages, which are the eyelids and eyebrows, the motor muscles of the eye, and the lachrymal apparatus.

The globe of the eye.—The globe of the eye is generally described as a spheroid, to which the segment of a smaller sphere is applied in front, and this definition is exact to the senses if it is not so mathematically. The walls of the globe of the eye are formed principally of two fibrous membranes: one white and opaque—the sclerotic (*scleros*, hard)—which envelops the two posterior thirds of the globe; and the other transparent, and resembling a horny plate, from whence its name, *cornea*. The sclerotic is one of the strongest fibrous membranes in the body; it is white on its external surface, and of a brownish-red colour internally; it is thicker at the posterior portion of the eye, where it opens to allow the passage of the optic nerve, than in front, where it terminates in a circular hollow or slope, into the border of which the cornea is set like a watch-glass. The two membranes are united by

intimate adherence, so strongly as to seem but one. The cornea is thicker than the sclerotic, and is composed of superposed layers perfectly translucent; it is convex in front, and concave behind, and appears to be circular, although its transverse diameter is a little greater than the other.

Choroid.—On the internal surface of the sclerotic is a vas-

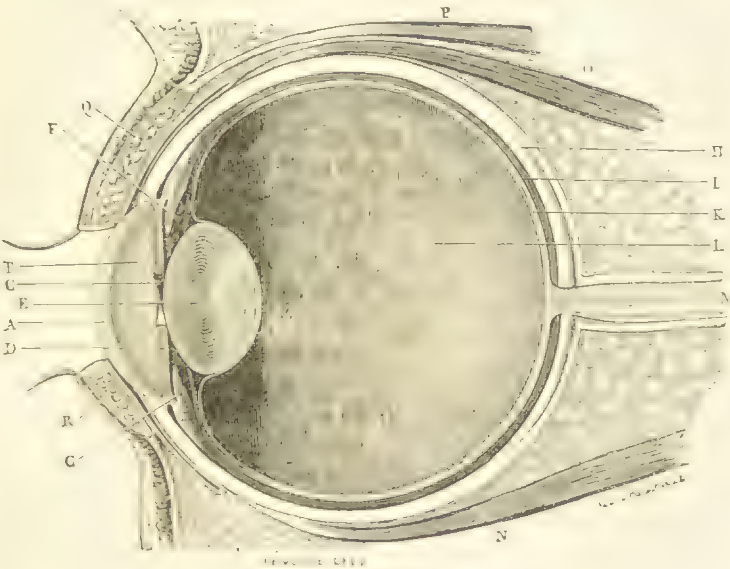


Fig. 34.—Vertical section of the eye on the median line.

A. *Cornea.*
B. *Anterior chamber.*
C. *Pupil.*
D. *Iris.*
E. *Crystalline.*
F. *Zone of Zinn, forming the anterior wall of canal of Petit.*
G. *Ciliary processes and circle.*
H. *Sclerotic.*
I. *Choroid.*
K. *Retina.*
L. *Vitreous body.*
M. *Optic nerve.*
N. *Right inferior muscle.*
O. *Right superior muscle.*
P. *Levator muscle of eyelid.*
Q. *Lachrymal glands.*
R. *Lachrymal canal.*

cular membrane called the choroid, which lines it closely from the bottom of the eye to the circumference of the cornea, and is attached to it by a very fine cellular tissue. The choroid is composed of two layers, of which the external corresponds to the sclerotic, and the internal, or *membrane*

of Ruysch, corresponds to the retina. These two layers, attached to each other by their internal surfaces, are covered externally with a layer of pigment, which is thicker next to the retina than on the side toward the sclerotic. The choroid is pierced behind by an opening, which gives passage to the optic nerve; in front, near the circumference of the cornea, it separates in order to form the ciliary circle and ciliary processes. The *ciliary circle*, *ring*, or *muscle*, is a little band, vascular, like the choroid, slightly adherent by its external surface to the sclerotic, and united by its lesser circumference to the cornea, at the point where the latter attaches itself to the sclerotic. Behind the ciliary circle a series of membranous rays are seen joined together, and forming a crown; these are the *ciliary processes* (from *processus*, prolongation, ray), the whole of which constitute the *ciliary body* or *disk*. These rays, which are attached to the choroid, like the ciliary circle, are of two kinds; one into which the crystalline is set, and which gives attachment to its capsule, termed the ciliary processes of the vitreous body; the others extend to the iris, behind which they form a sort of circular curtain, by folding back on themselves, and adhering to the larger circumference of this membrane. Thus fixed by one border, the ciliary disk floats by the other, like a fringe behind the iris, yielding to the slightest impulse which may be communicated to it. The ciliary processes are covered with a thick layer of pigment.

Iris.—In the space between the ciliary circle and the ciliary process the larger circumference of the iris is fixed. This is a muscular membrane, according to some writers, and vascular according to others, forming a vertical partition behind the cornea. The iris is pierced in the middle by a circular opening called the *pupil*. It represents exactly what is called a diaphragm in optical instruments. Its anterior surface is coloured in different shades according to the individual, but always remarkable for their delicacy or their intensity; the variety of which has given to the membrane the name of iris, or the rainbow. Its posterior face is covered with a layer of pigment, which is called the *uvea*.

It is well known that the pupil dilates in the dark, and

contracts on the contrary in a bright light, only allowing that quantity of luminous rays to enter the eye which is necessary to vision. Certain substances also when taken into the system act similarly on the iris; such are opium and the Calabar bean, which cause the pupil to contract; belladonna, on the contrary, dilates it. Changes in the diameter of the pupillary opening also result from certain affections of the eye and brain. Physiologists consider the dilatation and contraction of the pupil as belonging to muscular movements; in fact the microscope demonstrates the existence of muscular fibres in the iris; it contracts also under the influence of electricity.

It has been remarked that the posterior surface of the iris, the ciliary processes, and the choroid were covered with a layer of *pigment*. This name is also given to a dark brown substance, appearing black in a mass, which colours certain portions of the skin in the white man, and the whole tegument of the negro. In the eye this pigment plays the same part as the lamp-black in the interior of certain optical instruments, as the telescope and magic-lantern; it absorbs the luminous rays, and prevents them from being reflected, which would confuse the vision.

Retina.—The internal surface of the choroid, or rather the pigmentary layer which covers it, is lined by the *retina*, a nervous membrane, upon which the objects are depicted that we see. It appears to be formed by the expansion of the optic nerve, which enters the eye at its posterior part, and forms at the bottom of the globe an enlargement, which is called the *papilla of the optic nerve*. The retina develops itself from the papilla, around which it forms a fold, and extends over the cavity of the eye to the circumference of the ciliary processes of the vitreous body, where, according to Cruveilhier, it abruptly terminates. It is of an opaline white colour, semi-transparent, and easily torn. Its centre, which corresponds to the antero-posterior axis of the eye, is to the outside of the papilla of the optic nerve, where there is a yellow spot (*macula lutea*) and a depression (*fovea centralis*). The yellow spot seems to be the point in the eye where vision is most distinct. Microscopists describe the retina as being composed of five, or even eight layers, of which the

external one is vascular, and in contact with the choroid; the internal one, very important in a physiological point of view, is the *membrane of Jacob.* It is composed of cylinders, or *rods*, joined together like the stakes of a palisade, perpendicular to the plane of the membrane, and forming by their free extremities a mosaic, each microscopic division of which

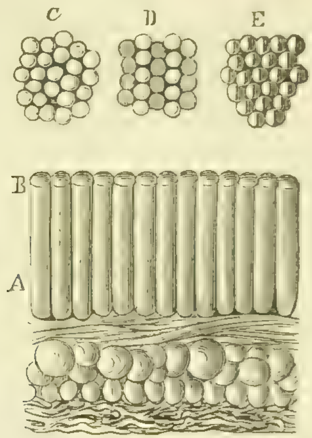


Fig. 35.—Rods of Jacob under the microscope.

A. *Rods of Jacob.*
B. *Their extremities forming surface of retina.*
C. *Retinal mosaic formed by the rods.*
D. *Points of the retinal mosaic receiving different luminous rays.*
E. *Points receiving each two different rays.*

is about 0·001 of a line in diameter according to Robin, and 0·0008 of a line according to Helmholtz; and represents a section of a rod. We shall see what part these terminal points play in vision.

Vitreous body.—The cavity of the globe of the eye in its three posterior quarters is occupied by a substance completely translucent, the *vitreous humor.* According to most anatomists, it is contained in an envelope called the *hyaloid membrane.* The vitreous humor and the hyaloid together constitute what is called the *vitreous body*, which is perfectly adapted to the retina throughout its whole extent, and in front takes the form of the posterior surface of the crystalline. According to those anatomists who admit the existence of the hyaloid,

it folds back on a line nearly corresponding to the border of the crystalline, and is continuous with the ciliary zone of Zinn, or the *ciliary processes of the vitreous body;* this zone embraces the border of the crystalline, around which it forms the *canal of Petit*, and adheres intimately to its capsule.

Crystalline.—This is the name given to a double convex lens, more curved posteriorly than anteriorly, translucent, and placed vertically in the axis of the eye, so that the axis of the lens corresponds to the centre of the pupil. The crystalline is formed of superposed layers, which are less consistent outside than towards the centre; it is contained in a *capsule*, which applies itself closely without adhering to it. The greater or less convexity of the surfaces of the crystalline modifies the power of the eye, determining whether the vision is long or short, *i.e.* presbyopic or myopic. The opacity of the lens, or of its capsule, forms the disease called *cataract.* We have already stated that its edge is set into the zone of Zinn, to which its capsule adheres.

Anterior and posterior chambers of the eye.—Formerly a certain space was supposed to exist between the crystalline and the iris; this was called the *posterior chamber* of the eye. We now know that the posterior surface of the iris is in direct contact with the anterior surface of the crystalline, and the posterior chamber is only an imaginary space. The interval which divides the iris from the cornea is the *anterior chamber*, which is filled with a fluid called the *aqueous humor*, translucent like the vitreous but less dense; it is secreted by the ciliary processes.

Muscles of the eye. Conjunctiva.—The globe of the eye is situated in the anterior portion of the orbit, beyond which it extends, and its axis, which is on the plane of that of the orbit, is directed inwards towards the centre of the base of the cranium. The eye is fixed in the orbit by an aponeurotic capsule, the optic nerve, and by six muscles which turn it in every direction. A mucous membrane, the *conjunctiva*, so named because it unites the eye to the lids, spreads over the anterior portion of the globe, as is proved by the injection of its vessels in some ophthalmic affections, and then folds back on itself, and lines the internal surface of the eye-

lids. According to some anatomists, it is not the conjunctiva, but only an expansion of its epithelium, which covers the cornea.

Eyelids.—An elliptical muscle extends in front of the orbit, which is formed of concentric fascicles, and which presents a transverse chink closed during contraction, and open in the shape of an almond when its fibres are relaxed. This is the *orbicular muscle of the eyelids.* Its ocular surface is covered by the conjunctiva, its external face by the skin, its opening is circumscribed by the edge of the lids, which are made firm by the *tarsal cartilages.* The upper lid is larger than the lower, and is raised by a special muscle, the contraction of which alternates with that of the orbicularis, which is its antagonist. The points where the eyelids are united by their commissures are called the *angles of the eye.* At the internal or greater angle of the eye, the conjunctiva forms a fold, the *semi-lunar fold*, which is in fact a rudimentary representative of the third eyelid (*membrana nictitans*) of certain animals. Inside of this fold is the *lachrymal caruncle*, a small glandular body of a rose colour, which is covered by the conjunctiva. The edges of the lids are ornamented with a fringe of silky hairs which protect the eye, and add greatly to its beauty. The greater or less extent of the opening of the lids makes the eye appear larger or smaller; the conformation of the palpebral muscles and the tarsal cartilages gives to the eye an elongated and languishing form as in the East, or round and bold as among the Occidentals; but the dimensions and form of the globe are the same in all countries and in all individuals.

The upper lid, which is attached to the arch of the orbit, is surmounted by the *eyebrow*, which is designed to protect the eye like a visor, and its movements play an important part in the expression of the face.

Lachrymal apparatus.—This is composed of, *firstly*, the *lachrymal gland*, which lies in a depression of the orbital arch, and of little glands of the same nature, which form a granular layer in the substance of the upper lid; *secondly*, of the *lachrymal canals*, by which the tears are poured out upon the conjunctiva, a little above the border of the upper lid; *thirdly*,

the *lachrymal ducts*, which are destined to receive the tears after they have bathed the eye, and of which the orifices or *lachrymal points* are seen near the internal commissure of the lids; *fourthly*, the *lachrymal sac*, in which the lachrymal ducts terminate, and which empties the tears into the *nasal canal.*

The tears by running over the surface of the conjunctiva render it supple and facilitate the movements of the globe and eyelids by lessening the friction. They serve the same purpose in the eye as the synovia does in the articulations. The influence of moral or physical causes increases their secretion, and the lachrymal ducts do not suffice to carry them off when they run over the lids.

Vision.—Among the phenomena, all of which constitute *the sight*, some belong to the domain of physics, and may be submitted to investigation, many may even be demonstrated by experiment; while others, on the contrary, are patent to the observation, but little known as to their cause or their mechanism, and await from the progress of science an explanation which physiology has as yet been unable to give. Even in those phenomena which at first seem purely physical, we must not forget that the refracting media of the eye are organized, and cannot be compared except by approximation to inorganic bodies, on the form and density of which physicists base their calculations. This is necessarily the cause of the differences in the theories promulgated in regard to vision; for although the eye may in some respects be considered as an optical instrument, we can never arrive at exact deductions by comparing organs analogous or even similar in their construction, but different in their nature.

Physicists claim as belonging to their proper province the visual phenomena produced between the cornea and retina; everything on the other side of that membrane belongs to physiology.

The retina renders the eye sensible of light, and we may therefore consider it as the essential organ of vision. The function of the other portions is to convey the luminous rays to its surface under conditions necessary to a nervous impression, which all combine to insure, but which is accom-

plished in the retina alone. Other causes besides the contact of luminous waves may excite the retina; thus the pressure of the finger on the eye for example, and the disturbance resulting from a fall or a blow on the head, the action of electricity, and certain affections of the eye and brain, give rise, in the absence of natural or artificial light, to luminous images varying in form and intensity. Light produced under these conditions is called "retinal light."

Like the optic and the other special nerves of the organs of sense, the retina has a special sensibility; it receives the impression from the light and transmits it to the brain, but it is *not* itself sensitive to touch. No mechanical irritation causes it the slightest pain. In a normal condition, the action of a too brilliant light, and in certain affections of the eye and brain, the least ray will cause a painful sensation, but this pain must be referred either to the encephalon or to the nerves of the iris or of the ciliary circle, independent of the retina and the optic nerve.

Punctum cœcum or blind point.—Mariotte was the first to recognize that all parts of the retina were not equally sensitive. According to most authors, a limited portion of this membrane, corresponding to the papilla of the optic nerve, is totally insensible to light. M. Longet admits that there it has, at any rate, a very obtuse sensibility. This "blind point" is the only one on the internal surface of the eye which is not covered with pigment.

If we trace two figures on a horizontal line on a piece of paper placed vertically (fig. 36, p. 161), and then shut the right eye, and fix the left on the right figure, at certain distances we can see both of them more or less distinctly: but varying the distance of the paper from the eye, there is a point when we only see the figure upon which the eye is fixed: the other disappearing entirely, but it reappears when we change the position of the paper, or cease to look fixedly at one figure. The greater the distance between the two figures, the greater must be the distance of the paper from the eye, in order to render one of them invisible. The image of the invisible one is then projected on the blind point, and it reappears, when by the displacement of the paper the angle which its

rays form with those from the other becomes more or less open.

Entoptics.—The eye perceives not only external objects, but certain details of its internal organization. This portion of the visual phenomena is called *interior vision*, or entoptics. A bruise of the cornea through the lids, or a scar or foreign body on its surface, the vascular ramifications of the retina, and other causes of that nature, sometimes throw images on the retina of different forms, such as striæ, spots, globules, dark or luminous circles which appear to move in the eye. Certain of these images are called flies, or motes (*muscæ volitantes*), because they traverse the field of vision from one side to the other. Their appearance results from nothing abnormal, and they cannot be confounded, when there is no other disturbance of the visual functions, with the analogous signs which accompany and denote some diseases of the eye and brain. A lateral movement of the eye is sufficient to displace them or cause them to disappear.



Fig. 36.

Reversed images. — The eye may be compared to an optical instrument known as the *camera obscura*. It is well known that the image of objects appears reversed on the screen of the camera; in the same manner the luminous rays which spring from every point of an object at which we look, traverse the cornea, the aqueous humor, the crystalline, and the vitreous body, in order to reach the retina; and are refracted in this transit, so that the image which they form appears reversed at the bottom of the eye. In examining the eye of an ox, of which the sclerotic has been previously made thin—or the eyes of albinoes, such as white

rabbits, for example, which are destitute of pigment, and in which the sclerotic and choroid are transparent, we may see, as Magendie pointed out, the flame of a candle reversed upon the retina.

How then are we able to see objects in their real position? Buffon and others have asserted that reason enables us to restore the image depicted on the retina to its real position, that touch enables us to rectify the visual sensation. But Cheselden, having by an operation enabled a patient born blind to see, does not state that the young man first saw objects otherwise than in their real position: and the careful observations made by this skilful surgeon do not permit us

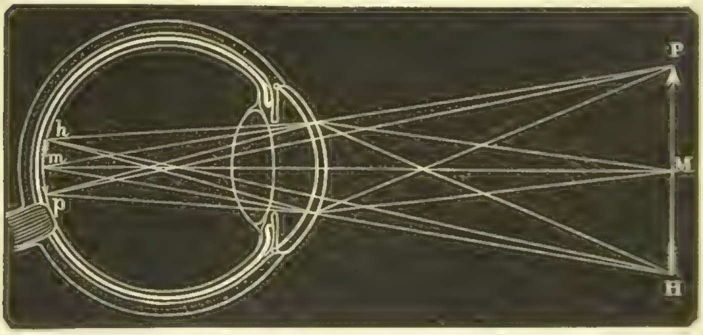


Fig. 37.—Course of the luminous rays in the eye.

H, M, P. *Luminous rays emanating from an object.*
h, m, p. Luminous rays refracted, forming the inverted image on the retina.

to suppose that a circumstance of such importance could escape his notice. According to M. Lamé, we know that objects are upright although we see them inverted, from the consciousness of the movements which we give to the optical axes of our eyes in looking successively at the different points of objects from top to bottom.

Müller avers that we see the objects inverted, but that all presenting themselves to us under the same relative conditions of position, nothing can appear inverted because we see everything in the same position, and that our notions of uprightness or inversion only exist by opposition.

M. Longet explains upright vision by supposing that every external luminous point is felt in the eye according to the direction it takes relative to us. We must, says this eminent physiologist, consider the concave spherical surface of the retina as formed of a mosaic, each elementary part of which is a sort of eye designed to perceive the different luminous impressions in a determinate direction. Every pencil of light emanating from a luminous point, and forming a cone of which the apex and the normal axis correspond to one of these portions, will be perceived in the direction of a line joining the centre of the spherical surface to the object looked at. If we reason in this way for every one of the points which constitute the whole of a visible object, the perception of each of these points will be in the real direction, and that of the whole will also be felt under the same conditions, in regard to the observer. The image therefore is not seen as a complete whole; each luminous point assisting in its formation making a separate impression on the brain, each one is felt according to the primitive direction of the ray of light, and the whole is seen in its real position.

Functions of the iris.—In order that vision may be distinct, it is necessary that the rays should enter the eye in the direction of what is termed the visual axis, and the various movements of the organ tend unceasingly to place it in a position to fulfil this condition, and it is necessary, also, that the light should be neither too strong nor too weak, and that the rays shall traverse the central portion only of the crystalline, and not its borders. In order to obtain an analogous result in some of their instruments, opticians divide them by means of a partition pierced by a hole in the centre, which is termed a diaphragm. We find a similar arrangement in the eye, "an intelligent diaphragm," to use the expression of M. Longet, that is the iris, which dilates or contracts the pupil in such a manner as to measure the quantity of light necessary to vision, and which only allows those rays to pass which are directed toward the central portion of the crystalline lens. In the dark, or if we look at an object but slightly illuminated, the pupil dilates in order to admit the greatest possible number of rays which are

refracted by the cornea; it is the same if we look at a distant object, the rays from which are less divergent; if this object becomes more luminous, or if we approach it, the pupil contracts in proportion.

Optic centre, visual angle, appreciation of the size of objects.—The rays emanating from two points of an object, P H (fig. 38), converge toward the *optic centre* O, at a point in the eye a little behind the crystalline, and thus form an angle P O H, which is called the *visual angle.* From the optic centre these

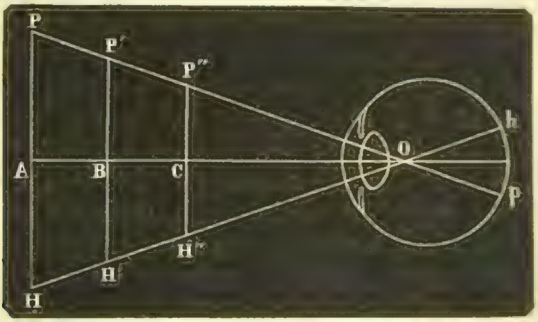


Fig. 38.

rays diverge to the retina, and form an angle, *p* O *h*, equal to the first, the base of which, corresponding to the retina, measures the size of the image which they form upon it. The visual angle therefore gives us an idea of the size of objects, and enables us to compare them, but in order that our ideas may be exact, they must be confirmed by our notions of distance. In fact, several objects of unequal size, P H, P′H′, P″H″, may be placed at such distances, A B C (fig. 38), as to subtend the same visual angle; we must therefore estimate their relative distance, in order to judge correctly of their size. We can also obtain a knowledge of their size, if we know that of any portion of the object which we see, or the size of another object placed at an equal distance. Thus, when we look at a ship at sea, we can judge of its size by that of the men whom we see upon it; the height of a balustrade enables us to calculate approximately that of the building of which it forms a part. When the means of comparison fail

us, it is very difficult to avoid errors, the very causes of which escape us. Thus, the sun and the moon when they are near the horizon, seem to present a much greater diameter than when high in the heavens. The atmosphere causes objects to appear near or distant, according as it is pure, or charged with mist. These illusions are frequent, especially among mountains, and the inexperienced traveller should not count too much upon the exactness of his impressions.

Bravais points out a very common error in drawing a rough hill-side in relief, or a mountainous horizon. In verifying a sketch mathematically, the horizontal distances of the different points in the landscape are found to be sufficiently exact, while the height of the summits, or of inequalities of surface, is in double proportion. But we must add, that the design adjusted mathematically seems incorrect in an opposite sense, and does not give the impression of the natural relief.

If a rainbow is formed over a cascade when the sun is near the horizon, and the circle of this bow is nearly complete, we seem to see not a circle, but an ellipse, of which the principal axis is vertical; the same illusion is produced when we look at a halo.

Visual impressions, separate or mixed.—If we look at a print placed at a certain distance, the details of the engraver's work disappears, the dots and the shading are confounded with the white lines which separate them, and the eye perceives only a grayish tint more or less distinct; so also, if a red and blue powder be mingled together, the mixture gives us the impression of a violet colour, although every grain of each powder preserves its own proper colour. This is explained as follows. We have already stated that the internal surface of the retina presents a mosaic of extremely small terminal divisions, each one of which acts separately, and transmits to the brain one single impression at a time. If the image of a trace of the burin or of a grain of powder covers one of these divisions, the impression is single (see fig. 35, p. 156); but if two lines, one white and the other black, or two grains, one red and the other blue, are so small and so near together, that their images are in juxtaposition on the same division of the retina, the impression is

mixed, and the brain perceives the sensation of gray or of violet. Or, in other words, in order that two minute luminous objects may be distinctly seen, the angle subtended upon the retina by their images must not be greater than the diameter of one of the retinal divisions. The distance of the two objects from the eye being determined, the measure of the angle subtended by them enables us to estimate the size of these divisions.

Accommodation of the eye to distances.—When we make use of the camera obscura, in order that the image may be distinct the screen must be placed in the focus of the instrument, that is at the point where all the rays refracted by the objective converge. If the objects recede or approach, the screen must be placed at a proportionate distance from the object-glass, so that its surface may correspond to the apices of the refracted luminous cones. And yet we see with equal distinctness the images of objects at very unequal distances, without any variation in the form of the eye, or the relative conditions of its media, or at least without our consciousness of anything but a scarcely perceptible effort. This power of *accommodation* of the eye has long been the subject of investigation, and the question is not yet settled. The most generally received explanation is, that in order to see objects at different distances, and especially very near to the eye, it modifies its form, or that of its media, and adapts itself to the distance in such a manner, that the retina is always in the focus. According to some authors, the length of the axis of the eye varies, the retina approaching or receding from the crystalline. Others maintain that it is the crystalline which changes its place, or that the curves of the refracting media modify themselves in such a manner, as always to make the apices of the luminous cones coincide with the immovable retinal surface. This theory of *adaptation* or *accommodation* is denied by some eminent savants, though a few of them approach it in attributing this phenomenon to the contraction and dilatation of the pupil; while others have endeavoured to demonstrate that the distance of objects from the eye may vary to a great extent, without the image undergoing any appreciable modification.

Helmholtz maintains that the anterior surface of the crystalline increases in convexity in looking at objects near at hand, and flattens when looking at a distance; the pupil contributes also to the accommodation by contracting in looking at objects near at hand, and dilating to see at a great distance. Nothing positive is known regarding the manner in which this change of form in the crystalline is effected. M. Helmholtz inclines to the opinion that the diameter of the lens is increased or diminished, and consequently it becomes more convex, or more flattened, according as the zone of Zinn, which is inserted into the crystalline capsule, is distended or relaxed by the action of the ciliary muscle.

Some simple experiments prove that the eye cannot see distinctly, without an effort of adaptation, two objects placed at unequal distances, and that the image distinctly perceived by the retina when placed in the focus, is so no longer when the focal distance is changed.

1. If we look with one eye at the heads of two black pins, placed in a line at the same level, but at different distances, we shall see one of them distinctly and the other vaguely. If we

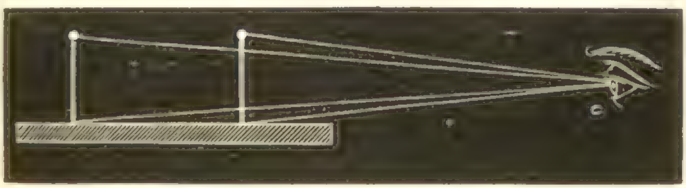


Fig. 39.—Accommodation of the eye to different distances.

look at the nearest one the image is perfectly clear, while the one farthest away is enveloped in mist; but if we look at the latter we see it easily without change of position, but when its image is well defined that of the other pin becomes confused.

2. In looking at a pin through a small hole pierced in a card, we can see either the pin or the edge of the hole distinctly; but when the image of one is distinct the other is confused.

3. By making two pin-holes through a card, at a distance

less than the diameter of the pupil, that is, not more than one-twelfth of an inch from each other, then look through these two apertures at a small object on a bright ground, at a black point, for example, on a sheet of white paper. At a certain distance the point is single, but if the head be moved backward or forward it will appear double.

In the first two experiments the eye is compelled to adapt itself to the distance, in order to see distinctly and successively two objects at unequal distances, and of which the images are not distinct, except when the apex of the cones formed by the refracted rays of light exactly corresponds to the surface of the retina, that is, when the retina is exactly in the focus. And also, the experiment of looking through a pierced card at an object, and seeing it distinctly, that is, looking at it through an immovable artificial pupil, seems to prove that the movements of the pupil are not necessary to accommodation.

The third experiment proves, that in order to see a single image the retina must be in focus. In this case, in fact, the rays coming from the external object converge and meet on the same retinal divisions, hence there is but a single sensation; if the eye approaches or recedes, they reach the retina either before their convergence is effected, or not until, having converged, they cross each other, and diverge beyond the focus, in either case in such a manner as to fall upon different divisions of the retina, and in consequence produce a double sensation.

The accommodation of the eye therefore seems to be incontestable, in spite of the want of accord in the opinions of savants upon its mechanism. A very little attention enables us to recognize the effort which accompanies it, especially if the adaptation is prolonged without variation at a short distance, as in looking through a microscope. Then, in fact, the eye loses sometimes for several hours the faculty of adapting itself to great distances; it becomes myopic for a certain time. Persons who are in the habit of using a glass for one eye, as watchmakers and engravers for example, are generally myopic in that eye; and this effect is very marked in infants, who acquire the habit of looking at objects near

at hand. Short-sightedness is thus much more common in towns than in the country. Sailors, mountaineers, and inhabitants of deserts are generally very long-sighted; the habit of looking at great distances doubtless develops this faculty.

Myopia, presbyopia.—The range of sight at which we read or write is, in a normal condition, about 12 to 14 inches; this point in myopia is much nearer, and in presbyopia much farther off; but for the latter, distinct vision does not go beyond 28 to 32 inches, that is, about double the distance considered normal; in myopia, on the contrary, this distance may diminish to within an inch. This condition of the sight is the result of modifications of the media of the eye. In myopia the cornea or the crystalline is more, and in presbyopia less, convex than in the normal condition. In myopia, therefore, the focus is in front of the retina for objects which, not being very near the eye, send to it rays which diverge but slightly; in presbyopia, on the contrary, the slight refraction caused by the flattening of the cornea, or the crystalline, tends to place the focus behind the retina, the point of convergence of rays coming from objects near at hand. The faculty of accommodation is rather limited in myopia, as well as in presbyopia, and is necessarily almost entirely wanting in the very near-sighted.

To remedy these modifications of the eye, the short-sighted person requires double concave glasses, which increase the divergence of the rays in proportion to the refraction by the media of the eye; the long-sighted person requires double convex glasses, which produce the opposite effect.

It is not uncommon to find persons who can only read and write at a very short distance, but who can notwithstanding see objects at a distance perfectly well. In this case only one eye is myopic, the other is normal. A slight inequality in the eyes is very common, and often unperceived. This is undoubtedly the reason that many persons use but one eye even when looking with both, without being conscious of it, and this inequality, which is either the cause or effect of this exclusive action, can only be augmented by it.

Short-sightedness, even when slight, is an infirmity from which its subjects suffer all their lives, and it may be aggravated by the use of too strong glasses, and, as we have already stated, by the use of the microscope. Long-sightedness, on the contrary, does not make itself felt much before the age of forty, and then only in persons whose sight is good. It is, as the name presbyopia indicates, a mark of age, and a little philosophy enables us to resign ourselves to it, and wear the glasses which were useless in youth.

Achromatism.—In ordinary vision objects appear to us in their natural colours distinctly defined, and not surrounded with the iris-like fringe which results from the decomposition

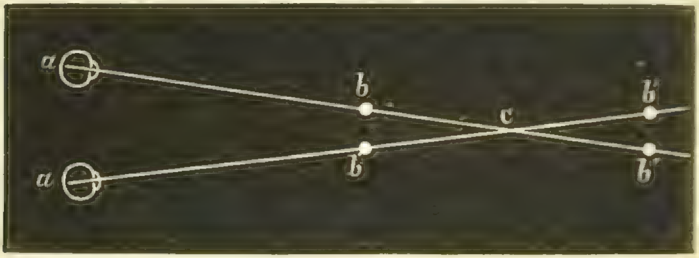


Fig. 40.

a, a. Globes of the eye.
b b, b' b'. Objects placed in front of or beyond the point of convergence of the two axes.
c. Point of convergence.

of light. It would seem therefore that the eye is *achromatic*. But the experiments of Arago, Frauenhofer, and other scientific men, prove that it does not absolutely possess this property, though it is only when placed under abnormal conditions that we discover this. If, for example, we look at an object, and adapt the eye to an imaginary point, either in front of or beyond it, the image both becomes indistinct, and its edges become rainbow-like. If a body is placed near the cornea, in such a way as to cover a portion of the pupil, the same effect is produced.

Single or double vision with two eyes.—Although a separate image is produced in each eye when we look at an object, the object appears single under normal conditions of the

sight, that is to say, when it is placed at the point at which the optical axes converge; but if the direction of one of these axes is changed, from pressing lightly with the point of the finger on the external angle of one of the eyes, for instance, the object appears double, and the images are separated more and more as the pressure is increased, and as it changes the direction of the axis more and more. On the other hand, two objects, one placed in front, and the other beyond the point of convergence of the two axes, but in the same direction, give but one impression, and we see but one.

Double or single vision with two eyes is explained by the correspondence of the terminal divisions of the retina in each eye. These are called the identical points. When the rays of light strike corresponding divisions in each eye, the sensation is single, but when they strike portions which do not correspond, it is double. This correspondence of the parts of the retina is shown by pressing lightly with the fingers on the closed eyes. If the internal or external angle of the eyes be pressed simultaneously, luminous images will be formed at the points directly opposite those which are pressed, and if the pressure be applied to the internal angle of one eye and the external angle of the other, or if we press the upper portion of one and the lower portion of the other, we see but a single image. From this we conclude that in the first experiment the two points pressed upon do not coincide because we see two distinct images, and that in the second they do correspond because we see but one. According to Müller, if we consider the retina as a sphere, the pole of which is the middle of the membrane or at some point in the same direction and at the same distance from the middle, the corresponding or identical points, on a section of this sphere, occupy the same meridian and the same parallel. Thus, in seeing with two eyes, the two images cause but a single sensation when they are formed on the corresponding portions of the retina, and consequently we receive a double sensation when they are placed on divisions which are not identical.

Stereoscope.—From what has been already stated it would

seem that in order to give but a single impression, the images perceived by both eyes should be exactly alike. But experiment demonstrates that two images differing in some respects, do notwithstanding give but a single sensation to the brain. When we look at a solid like the pedestal of a column or a monument, a moment's attention shows us that the outlines corresponding to the right of the spectator give a larger image to the right eye than to the left, and that each image differs from the other; the combination of the two sensations gives us the idea of relief.

If now we obtain by photography, or if we trace by a single white line on a black ground, the projection of this monument or pedestal, in conditions identical with those under which our eyes receive a double impression, the two images placed in the direction of the optical axes, as the surfaces would be which they represent, will give us the impression of the solid in question by a single image. We owe to Mr. Wheatstone the demonstration of this phenomenon, and the invention of an instrument which renders the proof very easy and simple. This is the *stereoscope*, the application of which is so widely known.

When the eyes are first applied to the instrument, in proportion as the optic axes converge, the two images are seen one over the other, and when at last we perceive but one, instead of a plane surface we have a relief under our eyes, which, in certain cases, produces a complete illusion. But as M. Longet observes, the unity of the image does not prove that there is but a single sensation, and the two different images do not give birth to a simple sensation, but are the source of one complex though indefinable one, that of solidity. How this blending of two different impressions is effected, is one of the mysteries of our organization; but the sensation of relief evidently arises from a combination of conditions different from those which determine single vision by means of two eyes.

When vision embraces a certain extent of space, as a landscape or a gallery of pictures for instance, the objects appear single to us, although for the most part they are out of the direction of the optical axes, but on observing closely we find

that we never fix the eyes except on a very limited portion of the space spread out before us; the objects thus normally seen occupy our whole attention, and turn it away from the other images of which the vagueness or duplication passes unperceived. When we endeavour to determine these facts we find that the boundary lines of the objects and the borders of the pictures appear double, but dim and confused, when outside of the point of convergence of the ocular axes.

Alternation in the action of the eyes.—When we look at two circles in the stereoscope, alike in size but of different colours, or if they are traced on white paper, and contain two different letters, we distinguish alternately one image and then the other, and when after a longer or shorter time we succeed in seeing them superposed, very soon they again alternate. The two eyes do not act simultaneously in experiments of this nature, and it is sometimes the impression produced on the right eye, and sometimes that of the left, alone which reaches the brain. This periodicity is especially regular in persons whose sight has the same range in both eyes. And we remark also that the distinct image is covered with spots of the same colour as that which is invisible.

This last phenomenon seems to indicate that the retina is not equally sensitive throughout its whole extent. The alternative preponderance of one eye over the other in vision is due to causes not thoroughly known, though it may be attributed, partially at least, to the fact that the eyes are unequal in extent of vision, or rather in skill in seeing. We almostly all of us use one eye more than the other in ordinary vision, and especially when we look attentively at an object. It is with the eyes nearly the same as with the hands in this respect, one is exercised more than the other, and it is generally the right eye. We have seen that the difference between the two eyes may amount to myopia in one while the other is perfectly normal. This inequality, even if slight, must tend to a difference in the power of accommodation and to discord in action which constantly inclines to cease and then to again reproduce itself.

As for the inequality in sensibility of the different portions of the retina outside of the *blind point* (punctum cœcum) the

displacement of the spots proves that it is not permanent. We know also that this partial insensibility may be induced by a brilliant light, and particularly by the rays of the sun. It is an experiment we all make involuntarily, and which will be discussed in another place.

Persistence of retinal impressions.—The impressions made by the luminous rays remain for a certain time, and are then gradually effaced; it is plain then, that if the action is reproduced at shorter intervals than the duration of the impressions, the brain perceives, not a series of sensations, but a continuous one. Thus in the rapid rotary movement of a burning coal, the eye perceives only a luminous circle, and when a wheel revolves rapidly, the spokes seem to approach each other and form a continuous surface. The impression of colour persists as well as of form; and if we cause a circle divided into party-coloured sections to revolve rapidly, they produce the sensation formed by a blending of them together: red and blue, for example, look like violet, and a great variety of different shades produce an impression as of gray. According to M. Plateau, the duration of impressions on the retina is about half a second.

This persistence of impressions has given rise to the construction of an apparatus, which is at the same time an object of amusement and a curious philosophical instrument. Such is, for example, the *phenakistiscope.* It was upon the same principle that the beautiful experiments were founded, by the aid of which Wheatstone measured the duration of lightning flashes.

Accidental images.—We may compare to a certain extent the action of light on the retina to that of pressure on an elastic surface. When the rays of any colour strike the retina, it resists the impulse of the luminous wave, and strives to regain a state of repose. When the action of light abruptly ceases, as when we close the eyes, for example, after a very short time, which is measured by the duration of the impression produced, the retina returns to its normal state by a reaction which is more energetic in proportion to the length or duration of the action. It passes by a sort of oscillation from the condition in which it was placed by the

luminous rays, that is to say, from the positive condition of impression to a negative one, and then forced by the reaction, it passes the point of repose, and recedes in an opposite direction. These oscillations continue for a variable time, growing feebler and feebler. The reaction of the retina, and the negative phases of impression, give rise to a new sensation independent of any external agent, by producing what are termed *accidental* or *consecutive images*.

We know that two colours are complementary to each other, which when mingled together produce white; but the accidental images have the peculiarity of presenting themselves in the colour complementary to that of the luminous rays which have excited the retina; thus, if we look steadily for a certain length of time in a very clear light at a wall painted red, the accidental image is green, and if the wall is orange, the image will be blue, &c.

If, on going into a dimly lighted gallery, we fix our eyes for a minute or two on a window which receives the diffused light, and then shut them suddenly and cover them so as to place them in complete darkness, the primitive impression of the window, with the panes lighted and the sashes dark, remains for a time, but very soon the consecutive image appears with the frame luminous and the glass obscure. This last image will appear sooner if a little light be admitted through the closed lids; but in all experiments of this kind, the eyeballs must be kept perfectly still under the veil with which they are covered, for the slightest change in the direction of the optic axes will cause the images, whether primitive or accidental, immediately to disappear.

One of the most important facts in this portion of the history of the eye, we owe to the observation of M. Plateau. It is that the duration of the uniform intensity of the retinal impression, up to the moment when it begins to decrease, is short in proportion to the intensity, that is in proportion as the light which produced it was brilliant and white; so the impression is less and less durable in its first intensity according as it is produced by looking at a blue, red, yellow, or white disk; if, on the contrary, we measure the impression not only in its period of uniform intensity, but from its

maximum to its minimum, it is long in proportion to the brilliancy of the light, that is to say, as the disk is white, yellow, red, or blue.

Several physiologists explain the formation of accidental images by persistent excitation of the retina with diminution of sensibility. They think that the light proper of the retina plays a part in this phenomenon.

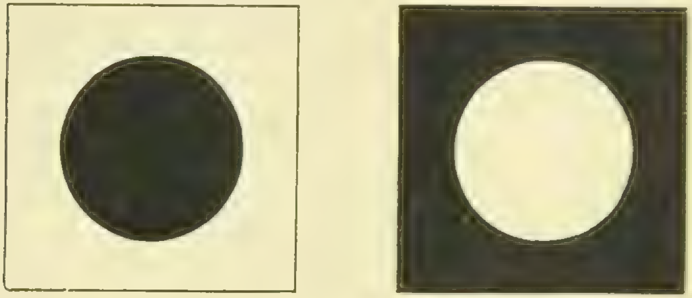


Fig. 41.—Irradiation.

Irradiation, accidental fringes of light.—When one portion of the retina is excited by the luminous rays, the vibration is extended to the neighbouring portions, and more strongly in proportion as the light is white; the result of this is, that of two objects of equal dimensions but of different colour, the lighter one in colour appears the larger in size. If a black circle is traced on a sheet of white paper, and a white circle of the same size on a sheet of black paper, and both placed at an equal distance from the eye, the white one appears larger than the black. In the same way, if we make a disk half white and half black, the white half appears the larger. In both cases the white encroaches upon the black, because the impression made by it upon the retina is more vivid, and the longer the experiment is continued the greater appears the difference in diameter. The name of *irradiation* has been given to the group of phenomena of this nature. It is the same cause which produces a ring of complementary colour around an image impressed on the retina by a coloured object. If a square of red be placed upon a white ground,

and the eyes are fixed upon it for a time, a border of pale green forms itself round the red; and in the same way a yellow square on a white ground produces a blueish crown round the yellow image: these are called *accidental fringes of light.*

M. Chevreul has discovered some remarkable laws which govern the contrast of colours, and the mutual influence which two colours placed in juxtaposition have upon each other. The investigations of the eminent professor are not more important for the arts than for science, for the phenomena of irradiation are produced constantly in vision, and artists should not forget them for a moment in painting or in architecture. It is unnecessary to remark that the harmonious or discordant effect produced by the association of colours in these two arts is of the utmost importance, and although in general the spectator troubles himself very little about the law of contrasts, yet he is notwithstanding very sensible of the impressions which result from its observance.

Daltonism—The effects of a disturbance in vision described for the first time by an English chemist who was attacked by it, are commonly designated by this term. It consists of a difficulty, more or less great, of distinguishing colours, some of which are entirely confounded although very different, as rose and gray, red and green, &c. Very marked cases of Daltonism are rarely met with, but in a slight degree the affection is not uncommon.

Apparent motion of objects.—Among the most common optical illusions we may cite those which consist of the apparent motion of external objects. When on a boat, for example, or in a carriage which is in motion, we seem to be at rest while the shore or the sides of the road seem to be in motion. We have no consciousness of the movement of external objects except by being ourselves at rest, and when the image of an object moves across the retina while the eye and the body are in repose, the object seems to change its position relative to us. Carried along by the boat or carriage, without our bodies taking any active part in the movement, we judge of the relative displacement instinctively, and from habit we refer to external objects the movements which we do not ourselves feel.

Sometimes there is an apparent displacement of objects, although neither the objects nor the eyes are in motion, but in a normal condition it is always after a movement of the body that this phenomenon appears. As when the body is whirled round rapidly and then suddenly stopped, everything seems to turn in an inverse direction. It is probable that the illusion then depends on the impulse to movement in a certain direction imparted to the brain; in fact, if we stop after turning round, the sensation of turning persists for some moments, especially in the head; and if we refer it instinctively to external objects, it is in consequence both of the persistence of the previous sensation, and of the idea of our actual immobility. We turn still, just as after having laid down a burden we continue to feel its weight upon us.

Gratiolet ascribes the apparent motion of objects under these circumstances to insensible oscillations, which displace to a limited extent the ocular axes, but he does not indicate the cause of these oscillations.

Optic nerve.—The visual impressions are transmitted from the retina to the brain by means of the optic nerve, of which that membrane appears to be the expansion. The two optic nerves converge from the base of the orbit toward the centre of the base of the skull, where there is an interlacement of their fibres in such a manner, that a portion of the right nerve goes to the left side of the brain, and a part of the left nerve to the right side; this is called the *chiasma*, or *commissure* of the optic nerves. Physiological theories, which are no longer tenable, have been deduced from this crossing of the nerves, and nothing positive is yet known of the relation between this disposition and the visual function. Mechanical irritation of the nerve seems to develop luminous impressions as in the retina, but it causes no pain whatever.

Movements of the eye.—The ocular globe is put in motion in the orbit by six muscles, grouped two by two, which raise or lower the eye, turn it inward or outward, or on its antero-posterior axis. In these movements the centre of the globe is immovable, and the eye moves around its transverse and vertical diameters. These three orders of movements are independent of each other, and may be made singly, or in

combination, in such a manner as to direct the pupil towards all points of the circumference of the orbit. The straight, superior, inferior, external, and internal muscles move it upward, downward, inward, and outward, and their successive action gives it a movement of circumduction. The two oblique muscles turn the eye on its antero-posterior axis, in such a manner as always to maintain the horizontal position of its transverse diameter, when the head or the body inclines to the right or the left. All these muscles take a direct or indirect part in every movement of the eye; if looking up or down, for example, the straight, superior, or inferior acts alone; the other muscles assure the movement, and confine it to the transverse axis. Such is the perfection of this mechanism, that the cornea is raised or lowered without the least lateral deviation, like the objective of a meridian glass; and the eye perceives by this succession of movements if the image of a line on the retina deviates 0·00002 of an inch from the vertical.

The eyelids follow the movements of the globe when it is raised or lowered, obeying the action of the muscles of which they receive the aponeurotic prolongations.

The movements of the two eyes are always symmetrical, and of the same kind; both are raised or lowered at once, directed to right or left, or around their axes; they can be turned inwards simultaneously to see an object very near at hand, or slightly outwards, when they turn from such a point to one in the distance. Even when one eye is closed, the globe turns in the same direction as that of the open eye. This unity and variety of movement contribute to make the eye the most important feature of the physiognomy.

Extent and delicacy of vision.—As regards the distance at which man can distinguish objects, he is less gifted than many other animals; but in every other respect his visual powers are at least equal to that of inferior beings. We know very little of the sensations produced in animals by colours; it seems probable that they have a relative perception of them to a certain extent, as the sight of red irritates the bull, for example; and we know that birds of prey from a great height in the air distinguish the colour as well as the form of

a lark or a quail hiding in the ploughed fields, although it so closely resembles that of the soil. But if we should suppose them endowed with sensitive faculties, useless within the limits of their instinct, could we find anything in animals more perfect than the organs to which man owes the prodigies of painting? We must, however, distinguish here between that which pertains to the visual apparatus, and that which proceeds from the intellect. The eye perceives the tints which nature offers in almost infinite variety; the mind compares them, and recognizes the elementary colours of which they are composed; the eye reflects in turn the model, the palette, and the picture; the mind perceives the relation of shades, and combines them in such a manner, that by mingling or contrasting them such a result is produced as conforms to the first impression; but in order that an artist may judge whether red or blue predominates in a violet tint, in order to appreciate the shade, the retina must transmit it to the brain in its purity.

At the manufactory of the Gobelins, we see the wools used in the fabrication of the tapestries arranged according to their shades. The number of these shades exceeds 28,000, and yet when we compare two approximate shades we distinguish them with facility, and perceive the interval which separates them.

The people who live in the country, seamen, and especially men living in a savage state, generally have sharper sight than the residents of cities. May not the habit of seeking to distinguish objects at a distance give the eyes a power which is not acquired when they always act within a limited horizon? Without assimilating exactly the effects of exercise on the eye to those which result from exercise of a muscle, we are justified in thinking that an almost incessant accommodation to great distances must influence the eye in that respect, and if, as is very probable, the accommodation takes place by the contraction of muscular fibres, the explanation of the increased range of the eye from exercise is very simple; but facts are wanting which verify and measure this increase in individuals. There is no doubt, however, that men from whom the horizon is habitually distant distinguish certain

objects at a point where they are confused to other persons, although within the reach of their vision.

A ship appears on the horizon, a man unacquainted with the sea can hardly distinguish the sails of this white cloud springing from the waters; but a sailor will tell you that is a brig or a three-master, a war vessel or a merchant ship, and often he will even come at its tonnage, its lading, its nationality, and its name. The Arab and the European in the midst of the sands of Sahara see on the horizon an object, which to the European is only a black point without appreciable form; the Arab sees a camel distinctly, and declares that it is at such or such a distance, without ever being deceived.

The inexperienced mountain traveller sees before him a chaos of slopes and abrupt walls, of elevations and windings, among which he can distinguish neither route nor practicable passage; but the mountaineer sees at once the accessible points, and the turns which he must take to reach the summit of the apparently impassable barrier. This proves not that the sailor, the mountaineer, or the Arab have sharper sight than the stranger to their country; but that they have learned to know the signification of such and such details of form, such a particularity of colour and the like, which are for them distinguishing marks, which seem to trace before their eyes the description which they give to their fellow-voyager of objects that are either confused or imperceptible to him. It is therefore to acquired notions, and skill in seeing objects, rather than to extent of vision, that they owe the faculty of distinguishing objects at great distances.

We find also in all countries, and in all climates, men who have extraordinary powers of vision. Wrangel speaks in his voyage to the Polar seas, of a Yakoute who related having seen a great star swallow little ones, and then vomit them up again. That man, says Wrangel, had seen the eclipses of the satellites of Jupiter. Humboldt tells, in his *Cosmos*, of a tailor in Breslau, named Schœn, who also had seen the satellites of Jupiter with the naked eye. No examples of a greater range of vision are known.

CHAPTER XII.

Sense of hearing.—Organ of hearing.—External ear; pavilion of the ear, auditory canal.—Middle ear; tympanum, drum, or membrana tympani, fenestra ovalis, fenestra rotunda, Eustachian tube, the small bones of the ear, muscles and movements of the small bones.—Internal ear; labyrinth, vestibule, semicircular canals, cochlea, membranous labyrinth.—Auditory nerve.—Noises and sounds; duration, pitch, intensity and quality of sound; passage of sound through air, water, solid bodies; gravity, sharpness of sound.—Mechanism of hearing; function of different parts of the ear; movement of sounds in the ear; propagation of sounds to the auditory apparatus by the vibrations of the bones of the skull.—Opinions of physiologists on the functions of different portions of the labyrinth; theory of Helmholtz.—Fineness and delicacy of hearing.—Correctness of the ear.—Estimation of the intensity, the distance, and the direction of sounds; ventriloquism.—Duration of auditory impressions.—Sensations having an internal origin.—Parallel between the eye and ear.

The ear.—The organ of hearing is not placed on the face, like those of sight, smell, and taste; but in the thickness of the base of the skull. But we may say it belongs to the face as one of the elements of the physiognomy, by its external apparatus, which contributes to the expression of the head. The ear is divided anatomically into three regions—the external, middle, and internal ear.

External ear.—This is the least complicated portion of the organ; it is composed of the pavilion, or projecting part, and the auditory canal.

The *pavilion of the ear* is similar, as the name implies, to the open portion of wind-instruments or a speaking-trumpet. It is an acoustic horn, which gathers the sonorous waves, and conducts them to the intricacies of the auditory apparatus. It consists of an elastic cartilaginous layer covered with a

delicate skin, and is curiously modelled. Its border, rounded in its upper portion, and folded back on itself, forms the *rim* or *helix*, and terminates at the lower portion in the *lobe*. The *concha* is in the centre, and is bounded behind by the

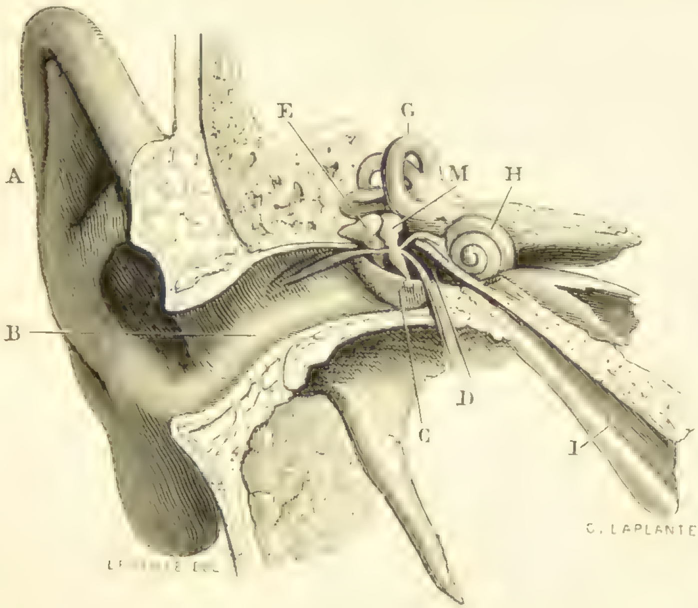


Fig. 42.—Section showing the different parts of the ear.

A. *Pavilion, or projecting ear.*
B. *External auditory canal.*
C. *Membrana tympani.*
D. *Tympanum.*
E. *Incus, or anvil.*
M. *Malleus, or hammer.*
G. *Semicircular canal.*
H. *Cochlea, or shell.*
I. *Eustachian tube.*

antihelix, and terminates in the auditory canal. The projections of the *tragus* and *antitragus*, separated by an elliptical slope, protect the orifice of this canal, and a down, which might be called the *lashes* of the ear, sifts the air as it passes into the organ.

The pavilion of the ear is directed forward, projects from the head, and its lines are in beautiful harmony with the oval of the face.

De Blainville compares the curves and the surface of the pavilion of the ear to those of the head. According to this naturalist the curve of the superior portion of the pavilion corresponds to that of the cranium, and the free border of the rim describes a curve parallel to that which marks the temporal fossa. When the head is not prominent in its middle region, and the temporal fossæ are slightly marked, the rim is absent; it is, on the contrary, broad and prominent when the arch of the skull overhangs the temporal fossæ. The concha corresponds to the upper jaw, and is proportional to it; and the prominence of the origin of the helix represents that of the zygomatic arch; and lastly, the profile of the lobe is like that of the upper jaw. It is remarkable that this lobe exists only in man, and that man only has also a prominent and angular chin.

The *auditory canal*, which represents the tube of the acoustic trumpet formed by the external ear, is cartilaginous next the concha, and the remaining part is excavated in the *petrous* or stony portion of the temporal bone. This canal is about one and a fifth inch in length, and its entire disposition is such that foreign bodies suspended in the air cannot pass with it to the membrana tympani. It is bent near the concha in such a manner that the air, in transmitting sound to the middle ear, does not penetrate in right lines, thus protecting the sensibility of the membrane.

The middle ear.—The *membrana tympani* (membrane of the drum), of which the name indicates the function, is a membranous partition stretched obliquely across the bottom of the auditory canal, which it separates from the middle ear or drum. This membrane is semi-transparent and very thin, although it is composed of three layers; it vibrates under the impression of the sonorous waves, and transmits the vibratory movement to the little bones of the ear. Between the membrana tympani and the internal ear is the *drum* or *the tympanum*, a cavity hollowed out, like all those of the middle and internal ear, in the petrous portion of the bone. Among the details of its form and organization, we remark the *fenestra ovalis*, which communicates with the vestibule, and the *fenestra rotunda*, which leads to the cochlea. The drum

also communicates with the *mastoid cells*, numerous sinuses which are found in the mastoid process of the temporal bone, containing air, and designed to multiply the vibratory surfaces; and lastly, it unites by a sort of funnel with the Eustachian tube, a canal about one inch and a third in length, which opens into the upper portion of the pharynx, and admits the air into the middle ear.

The ossicles or small bones of the ear.—These are four in number; they are articulated together, and form a bony chain which runs from the membrana tympani to the fenestra ovalis, following a broken line. They have been named the *hammer* (*malleus*), the *anvil* (*incus*), the *lenticular* bone, and the *stirrup* (*stapes*), from their form or their functions. Special muscles act upon the malleus and the stapes, which are at the two extremities of the chain; the incus and the lenticular bone serving as media for the propagation of the vibrations. The motion impressed upon one of these extremities is communicated to the other by a sort of see-saw movement of the little bones, the mechanism of which is pretty nearly represented by that of a bell. One extremity of the hammer, the handle, is fitted into the membrane of the tympanum, and when the muscle of the hammer contracts, the membrane tightens, a phenomenon which will be discussed further on. The muscle of the stirrup attaches the flat part of this bone to the fenestra ovalis, and according to M. Longet prevents it from being forced in a contrary direction under the influence of the muscle of the hammer, of which it is the antagonist.

Labyrinth or internal ear.—The internal ear is that portion of the organ of hearing which perceives the impression of sound, and transmits it directly to the brain. It is hollowed out in the petrous bone, and is divided naturally into three distinct compartments, named the *vestibule*, the *semicircular canals*, and the *cochlea* or snail-shell. These divisions form together one of the most complex and delicate pieces of mechanism in the human body.

The labyrinth is composed of a bony cavity which incloses a membranous cavity in a portion of its space, and from this circumstance arises the distinction made by anatomists

between the osseous and membranous labyrinths. We shall first consider the osseous labyrinth.

The *vestibule* is an ovoid cavity placed in the centre of the internal ear, between the semicircular canals and the cochlea. It communicates with the drum by the fenestra ovalis, which is closed by the base of the stapes. In it are seen the openings of the five semicircular canals, of the vestibular stair of the cochlea, and of the vestibular canal. This latter is the opening of a vascular canal which traverses the petrous bone.

Semicircular canals.—This is the name given to three curved tubes forming axes of circles, one which is horizontal and is placed between the two others, which are vertical. They are each enlarged into a bulbous cavity (*ampulla*) at one extremity, and communicate with the vestibule by five orifices.

Cochlea (or snail-shell).—This is the name given to a conoid cavity which is separated from the semicircular canals by the vestibule, with which it communicates, and terminates at the fenestra rotunda. The cavity of the cochlea is a spiral, describing two turns and a half round its *columella* or axis; it is divided transversely into two portions by a partition—the *lamina spiralis*, throughout its entire length. That portion opening into the vestibule is called the *scala vestibuli;* and that opening into the fenestra rotunda the *scala tympani*—by which it would, if it were not for the membrane which closes it, communicate with the cavity of the tympanum.

The *lamina spiralis* is divided lengthwise into a bony portion, which corresponds at its internal border to the axis; and a membranous portion, which attaches the osseous portion to the external wall of the cochlea. This wall is formed by the spiral plate. The cochlea is lined by a fibro-mucous membrane, which appears to be a continuation of the periosteum of the other two cavities of the labyrinth; the membranous portion of the spiral plate may be considered as a prolongation of the membranous labyrinth. Lastly, the vascular canal, called the canal of the cochlea, analogous to that of the vestibule, communicates also with the cavity of the skull. The base of the cochlea rests on the bottom of

the internal auditory canal, by which the auditory nerve enters the organ of hearing.

Membranous labyrinth.—The bony walls of the vestibule and of the semicircular canals inclose and protect a membranous apparatus of the same form, which is separated from them by a space filled with a limpid fluid called *perilymph* or *liquor Cotunnii.* The membranous labyrinth is therefore smaller in proportion than the osseous; the difference in size is about one-half. Its cavities contain a fluid analogous to the perilymph, and which De Blainville has compared to the vitreous humor of the eye; they also contain semi-transparent tubes and membranous sacs, the appearance of which is closely analogous to that of the retina. The membranous vestibule is composed of two distinct parts, the *saccule* and *utricle*, in which there exists a calcareous dust, which appears to represent in man and the mammifera the auditory stones or *otoliths* of fishes.

Auditory nerve.—The auditory or acoustic nerve specially belongs to the organ of hearing, and is remarkable for the softness of its texture; it enters the ear by the internal auditory canal, and divides into two branches, one of which distributes itself to the vestibule and to the ampullar extremities of the semi-circular canals; the other goes to the cochlea, and has been called the cochlear branch. Its ramifications are extremely minute; they line the surface of the modiolus and spread themselves regularly over the spiral plate, diminishing in length from the base to the summit in such a manner that if we suppose the spiral plate to be placed upright, and forming a triangular plane, these filaments would resemble the strings of a harp—the longest at the base of the triangle and the shortest at the summit. They are called *the fibres of Corti*, from the anatomist who first described them. The microscope enables us to count more than three thousand, and we shall see later the part they are supposed to fill in audition.

But before opening the physiological question, we will notice summarily some of the phenomena, the existence of which is revealed to us by the ear.

Noises and sounds.—Physicists divide sounds into two

classes—*musical sound* and *noise*. They both have the same origin, the vibrations of a body transmitted to the air. The short duration of a *noise*, and the lack of isochronism in its vibrations, do not permit us to appreciate its musical value, and this distinguishes it from *musical sound*. Thus the explosion of gas or powder, the crack of a whip, or the breaking of a branch make a noise, but give no musical sound. The limit between sound and noise is otherwise insensible, and varies according to the individual. A noise as well as a sound may be grave or acute, feeble or intense. The difference in the duration of the sensation does not permit us to compare noise to sound, but yet the ear seizes the relation between two noises as well as between two musical sounds.

A sound is called *musical* when its pitch can be estimated absolutely and relatively to other sounds grave or acute; or, in other words, when the number of vibrations follows a constant law and can be determined.

Whatever may be the difference, however, between a noise and a musical sound, the one is only a variety or degree of the other, and both, proceeding from the same source, may be studied under the generic denomination of *sound*.

Sound has four fundamental properties—duration, pitch, intensity, and *timbre* or distinctive quality. The three first named are defined by the words which express them; as for the *timbre*, it is the resonance peculiar to each instrument, to each voice, which enables us to distinguish without difficulty the notes of a violin, a clarionette, or a flute, and to recognize individuals by hearing them speak or sing.

The *duration* of a sound is measured by the time that the body vibrates from which it proceeds; it is *high* and *acute* according to the number of vibrations, and its intensity is measured by the amplitude or range of the vibrations which cause it, and this amplitude is in proportion to the force acting on the sonorous body.

The "*timbre*" of sounds was long an insoluble enigma to the physicist and the physiologist. J. Müller had suspected its origin in attributing it either to the isochronism of sonorous waves of different velocity, or to waves of different

length, producing a compound wave of a peculiar form, or else to a longitudinal vibration in the sonorous body taking place at the same time as the transverse vibration. M. Longet states, with greater precision, that the timbre of the human voice, and of wind-instruments, results from the co-existence of several sonorous waves of different tone and intensity, which modify the general form of the principal wave. But at last the beautiful experiments of M. Helmholtz have demonstrated, that the timbre of a sound depends upon the number of the harmonic notes which are produced at the same time as the fundamental note, and upon their relative intensity.

When a cord of a piano giving the C, for example, is struck, that note is heard, but a little attention enables the ear to hear other simultaneous and weaker sounds; they are the result of partial vibrations which take place in the length of the cord, according to certain laws which cannot be explained here. The C given by the shock impressed on the cord is the *fundamental note*, the other notes which are superposed upon it are the *harmonics*. From their fusion with the fundamental note, there results to the ear a complex sound which it decomposes instinctively into simple sounds, but they cause only a single sensation in the brain, that of a C having a special timbre. Whether the fundamental note be given by an instrument or by the human voice, the same phenomena are produced, and the timbre proves equally characteristic to the ear. The timbre is therefore the distinctive quality of the sonorous body—the form, in a certain sense, of sounds.

Sound moves more rapidly in warm air than in cold; its velocity in the atmosphere is 1118·45 feet in a second at 16° C. (60·8° F.) or 1086·37 feet at zero, according to experiments made by the Bureau of Longitudes in 1822; and according to those of Bravais and Martins made in 1844, it is 1092·89 feet at zero (Cent.) This velocity is not modified by the variations in the pressure of the atmosphere, and it is the same whether in a horizontal, vertical, or oblique direction. It is increased or diminished by the wind, according as it blows in the direction of the sound or contrary to it, though the

velocity is not changed if the wind blows perpendicularly to this direction. Sound cannot be produced in a vacuum, and it is therefore less intense in proportion as the air is more rarefied. It is weaker, for instance, on the tops of high mountains than in the lower strata of the atmosphere, although the profound silence which reigns at times in these elevated regions permits even very feeble sounds to be heard at great distances. We were enabled to prove this with M. Martins in 1844. Near St. Chéron (Seine-et-Oise), at an elevation of 459 feet, a diapason placed on a drum could be heard in the daytime 277 yards off; while on the great plateau of Mont Blanc, at a height of 13,123 feet, the sound of the same instrument could be heard at a distance of 368 yards. On the top of Mont Blanc, we could hear our guides talk at a distance of 437 yards, and they could hear us speak also.

Humboldt observes that sound is more intense and is propagated farther in the night than in the daytime, in spite of the noises and of the wind which in tropical countries increase after sunset. This diminution in sounds during the day is attributed by the illustrious observer to the unequal temperature of the strata of the atmosphere, under the influence of the sun and the radiation from the earth.

Sound moves much more quickly in water and in solid bodies than in the air. Colladon and Sturm found its velocity to be 4708 feet in a second in the waters of the Lake of Geneva at 8° C. (46·4° F.) of temperature; according to the experiments of Biot, its average velocity is 10,663 feet in cast-iron pipes. This is about five times greater in water than in air, and nine times greater in the pipe.

Humboldt records that sometimes volcanic detonations have been transmitted through the earth a distance of 500 to 745 miles.

It is stated that the gravest sound which can be perceived by the ear is 32 vibrations in a second (16 according to Savart), and the most acute, according to Despretz, is 73,700 vibrations. A sound of 60,000 vibrations is, according to M. Martins, very feeble, difficult to hear, and of such sharpness as to cause a painful impression on the ear. The

sounds which are easily perceived and appreciated by the ear vary from 100 to 2000 vibrations. The gravest C of a piano of six octaves and a half counts 128, and the most acute 8192.

Mechanism of hearing.—The sonorous waves penetrate directly into the auditory canal, or after they have encountered the outer portion of the ear, the sinuosities of which they follow, and the ear itself vibrates to the shock of sounds, and these vibrations are transmitted gradually to the organ. Savart, who has demonstrated this phenomenon by experiments, observes that the very irregular surface of the ear always presents some portion at an angle most favourable to the sonorous waves, whatever may be their direction; in fact, the force with which they act upon its walls is in direct proportion to their approach to the perpendicular.

If, for example, the pavilion of the right ear be covered with some substance which obliterates all the inequalities and transforms it into a plane surface, a sound cannot be heard on that side so well as on the left, when produced at an equal distance from both ears. It is to be presumed, also, that the pavilion, which increases all sounds equally, does not vibrate in unison with any one sound, nor has it, owing to the irregularities of its surface, any one peculiar to itself. And finally, the form of the pavilion, and its inclination in relation to the head, seem to have a certain influence on the acuteness of hearing.

Besides the vibrations which enter directly into the auditory canal, and those which come from the pavilion, this canal receives also those of the bones of the cranium and transmits them to the tympanum. These last and those of the pavilion reach the tympanum sooner than the first, for the reason already stated, that sounds move more rapidly in fluids and solids than in the atmosphere. It receives therefore two orders of vibrations, but in passing to this membrane the vibrations of the air are transformed into those of a solid body; from which we may conclude with Savart and Müller, that the function of the tympanum is to serve as a medium between the air and the small bones of the ear, by changing, as we have just seen, the atmospheric vibrations.

Sounds, augmented by the external ear, and concentrated upon the tympanum, are transmitted to the little bones, and again augmented during this transit, by a more close concentration upon the base of the stapes.

We have seen that the contraction of the muscle of the hammer causes tension of the tympanum. This membrane then passes from a state of repose to a variable degree of tension, upon the effects of which physiologists are not agreed. According to Bichat, it is more tense in proportion to the feebleness of the sounds, and to the greater necessity of action of the organ in order to perceive them. According to Müller and Savart, the tension protects the organ of hearing against too violent sounds by lessening the conducting power of the tympanum. According to Longet, the muscle of the malleus has no other function than to obviate variations in the tension, and especially to prevent the entire relaxation of the membrane; in a word, it is the key of the tympanum.

The sonorous waves traverse the chain of little bones, and are transmitted by it to the fluid in the labyrinth, thus changing their medium without losing their intensity. If the little bones were articulated in such a manner as to form a rigid straight line, instead of an elastic broken one, the distance between the tympanum and the fenestra ovalis being susceptible to variation, the result would be that in certain cases the pressure on the tympanum and on the fenestra ovalis would be too great, which the elasticity of the chain and its articulations prevent. The tympanum can only exert a limited pressure on the fenestra ovalis, and when it is at its greatest distance from it, the stapes is held in its place, in front of this opening, by its muscle. This is the theory of Savart, which was adopted and developed by M. Longet.

The walls of the tympanum inclose air, which propagates the vibrations from the tympanum, and transmits them by means of the membrane of the fenestra rotunda to the fluid of the labyrinth. These vibrations lose their intensity on becoming aerial, and this fact has led to the idea that possibly they may differ in their timbre from those transmitted by the little bones.

However this may be, the principal use of the air in the cavity of the tympanum is not to transmit the vibrations of that membrane; but to balance the pressure of the atmosphere on its external surface, and thus to render it completely independent between two equal pressures. This is effected by means of the Eustachian tube, which conducts the air into the middle ear. The temporary obstruction of this canal induces buzzings in the ear, causing temporary deafness, which is intensified by its entire obliteration. The canal also serves as an outlet for mucus and other fluids, which may be secreted in the cavity of the tympanum.

The sonorous waves enter the vestibule by the fenestra ovalis; this opening is closed by the base of the stapes, and receives the vibrations from the chain of little bones. The membrane of the fenestra rotunda transmits to the scala tympani of the cochlea the aerial vibrations of the cavity of the tympanum. This membrane, as Scarpa has remarked, is a secondary tympanum.

On reaching the labyrinth the vibrations are propagated to the fluid which bathes it, and thus reach the membranous labyrinth, and the scala vestibuli of the cochlea, where finally they encounter the extremities of the ramifications of the auditory nerve.

Besides the sonorous aerial waves, the ear perceives, as has already been stated, those which have been caused by an impression on the bones of the skull. Thus, when a sonorous body is held between the teeth, or against the walls of the cranium, the sound is perceived by the auditory apparatus. It is in this way that, in spite of the loss of the tympanum and the small bones of the ear, some persons can still perceive sounds of external origin. But it is indispensable that the membranes of the fenestra ovalis and fenestra rotunda, which close the openings of the labyrinth into the cavity of the tympanum, should still remain perfect, and that the fluid of the labyrinth should still bathe its cavities. But, as may be easily conceived, hearing under these circumstances is very limited, since it can only take place when the sonorous body is in contact with the bones of the head.

The functions of the three divisions of the labyrinth have

been differently stated by different physiologists. According to Dugès, the vestibule concentrates the sound, measures the intensity, and consequently judges of the distance. It has been supposed that the semicircular canals either give the idea of the direction of the sonorous waves, and of the position of the body from whence they emanate, or are simply organs for increasing the sound. De Blainville thinks that the function of the cochlea is to appreciate very acute sounds; Dugès makes it the musical portion of the auditory organ, the appreciator of notes, and the special apparatus for the perception of voices and articulate sounds.

Other authors have thought that the spiral plate (lamina spiralis), which narrows regularly from the base to the summit of the cochlea, corresponds to the scale of notes, from the gravest to the most acute, and that it vibrates in unison with each one of them.

According to Müller and Longet, the object of the cochlea is to furnish a solid plate upon which to spread the nervous filaments, in contact with the bony walls of the labyrinth and of the head, as well as with the fluid of the labyrinth; thus being able to transmit to these filaments the vibrations communicated to the solid or fluid portions of the auditory apparatus. And also, the spiral form of the cochlea gives in the least possible space a relatively large extent of surface for the expansion of the nervous filaments.

This diversity of opinion is easily understood, the moment we pass from natural facts to physiological speculations.

The auditory nerve is distributed to every portion of the labyrinth; but before entering it, while in the internal auditory canal, it divides into two branches, the smaller one running to the cochlea, and the larger to the vestibule and the semicircular canals. If we admit that the two branches are homogeneous, and only constitute two divisions of the auditory nerve, we must conclude that the auditory impression is perceived all over the labyrinth, just as the visual impression is felt on every portion of the retina. The division of the nerve, and the peculiar disposition of the ramifications in each of the labyrinthine cavities, seem to indicate a special function for each of these cavities. It seems natural to sup-

pose that apparatus so different in form, and so distinct in the different parts of the organ, should have a special object, and that they combine their functions to produce the complex sensation of hearing. Müller has demonstrated that the same aerial vibrations act with much more intensity on the fluid of the labyrinth, after having traversed the chain of small bones and the fenestra ovalis, than they do after traversing the air in the cavity of the tympanum, and the membrane of the fenestra rotunda; he thinks that the waves of the same sound transmitted through the two fenestræ differ not only in intensity, but also in their timbre up to a certain point, since those reaching the fenestra rotunda are aerial vibrations, and those reaching the fenestra ovalis, by the chain of small bones, are in the state of vibrations of solid bodies. But the cochlea also receives sonorous waves of both kinds by the scala tympani and the scala vestibuli; and farther, the cavities which form the labyrinth communicate with them, all being filled with a common fluid, and all united by their walls; they would seem therefore to be bound together up to a certain point as regards auditory impressions, and nothing demonstrates that vibrations are electively directed in their movement on leaving the vestibule, either toward the cochlea or the semicircular canals.

It must be admitted notwithstanding, that authors generally agree in placing the principal, and indeed only seat of auditory impressions in the cochlea, and this is the doctrine now professed by M. Helmholtz, to whom we owe our knowledge of the origin and mechanism of the timbre of sounds. We will briefly state his theory of hearing.

We have already seen that the terminal filaments of the acoustic nerve spread themselves regularly side by side over the lamina spiralis of the cochlea, like the cords of a keyboard; the eminent professor of Heidelberg compares these nervous filaments to the strings of a piano, and explains their functions in the following manner. If the piano be opened, and a person sings loudly above the strings any note whatever, the sonorous waves cause the strings which respond to the harmonics of the voice, to vibrate also; each one of these strings vibrates exclusively in unison with one har-

monic, and the note is thus decomposed by their sympathetic vibration. The same phenomenon takes place in the internal ear. The fibres of Corti decompose the sounds, each one vibrating in unison with the harmonic with which it accords, and these vibrations transmitted collectively to the brain by the acoustic nerve give the sensation of the fundamental note, and of its timbre. But here, as in every other instance, the living organ is infinitely superior to the machine constructed by man. The fibres of Corti number upwards of three thousand, and this gives four hundred sensitive cords to each octave, of which the interval or space is one sixty-sixth of a note. It is easy to understand from this how a cultivated ear can appreciate the slightest difference in sounds, as the eye perceives the least difference in the degrees of light.

This theory explains one of the most mysterious parts of the mechanism of audition, it shows us the sonorous waves exciting the Eolian harp of the acoustic nerve, just as direct observation enables us to see the luminous image painted on the retina. Just as a mirror and the camera obscura represent the eye, an instrument of music represents the ear; and we follow the sonorous and the luminous waves to the point where all is shrouded in mystery—to sensation, to comprehend which we must as little pretend, as to penetrate the mystery of life, or of our own intelligence.

But the ingenious explanation of M. Helmholtz does not at first seem to make the phenomena of hearing as accessible as those of seeing have become by means of optical instruments. The convex mirror, and the productions of photography, show us magnificent monuments and vast landscapes reproduced in microscopic proportion; we have nothing like this for the ear, and we are involuntarily led to contrast the auditory organ and its fine canals with the grandeur of sounds, and of the bodies from which they emanate. Physicists admit that the sonorous waves cross each other in the air in nearly the same manner as in a fluid, without modifying their curves, and it is thus that the distinctness of each particular sound is perceived in an accord executed by several different instruments; but, in order that this pheno-

menon of hearing may be displayed, the sonorous waves must move through the windings of the labyrinth with the same facility that they traverse space; the rush of meteors, and the immeasurable voices which nature has given to the atmosphere, to the ocean, and to mountains, must be transmitted to our ears in their relative proportions, as well as the sound of a falling dew-drop. How can the ear in its infinitesimal proportions perceive with equal precision the sound of the gigantic instruments which vibrate under the hand of nature, and the feeblest noise which traverses the air?

Let us remember that if we get a glimpse of the details of natural phenomena, and of those movements which constitute life, it is not in considering them as a whole, but in analyzing them as far as our limited means will permit. In the vibrations of the globe of air which surrounds our planet, as in the undulations of the ether which fills the immensity of space, it is always by molecules which are intangible for us, put in motion by nature, always by the infinitely little, that she acts in exciting the organs of sense, and she has modelled these organs in a proportion which enables them to partake in the movement which she impresses upon the universe. She can paint with equal facility on a fraction of a line of space on the retina, the grandest landscape or the nervelets of a rose-leaf; the celestial vault on which Sirius is but a luminous point, or the sparkling dust of a butterfly's wing: the roar of the tempest, the roll of thunder, the echo of an avalanche, find equal place in the labyrinth whose almost imperceptible cavities seem destined to receive only the most delicate sounds.

Acuteness and delicacy of hearing.—It has been said that hearing is the most perfect of the senses in man. Considered as a musical instrument the ear is in fact a most admirable organ, and which man alone possesses; but here, as in the eye, we must distinguish between the apparatus of hearing and what pertains to the domain of the mind. The ear perceives sounds, but the mind estimates their regularity, measures their intervals, judges them melodious or the reverse, determines their discord or their harmony. If the

painter is provided with a faithful mirror, the ear is for the musician a still more infallible guide; not that it surpasses the eye in delicacy of mechanism, but that the mathematical divisions of sound, and of their intervals, much more minute than shades of colour, do not admit of confusion. The eye perceives a great number of tints at the same time, which may mingle upon the retina either from their vicinity, or from the rapid displacement of objects, as we see when the molecules of two colours are mixed together, and when a disk of several colours turns on its axis. On the contrary, however rapid the movement in a piece of music, each note produces a distinct sound, and when several reach it simultaneously they always cause isolated impressions. It is thus that a musician in the midst of the accords of a large orchestra is able to distinguish a false note and the instrument from which it proceeds.

The acuteness of hearing has more influence upon the delicacy of auditory impressions, than extent of vision has upon visual impressions; acute vision is not necessary to the painter in judging exactly of colours, but the ear of the musician must have an exquisite sensibility in order that he may appreciate the truthfulness of notes and their harmonic relations; but when once this idea is acquired it is ineffaceable, and enables him to create master-pieces which his ear cannot hear. Beethoven became deaf at forty, and composed all those immortal works which for himself were never performed except in his mind.

It is not rare to find persons who distinguish musical sounds with difficulty and confound them as regards the notes. For those in whom this *Daltonism of the ear* is extreme, music has no existence; they hear only a succession of sounds more or less intense, without harmonious relation or rhythmical succession. Between this condition and that delicacy of ear which marks the leader of an orchestra or a good tuner, the degrees are infinitely varied, and absolute correctness of ear is as rare, at least, as a perfect perception of colour, although musical impressions seem to demand less effort, and to be a more common endowment than the ability to appreciate painting.

It is said that a false note disturbs more than false colouring, but this is true only within certain limits. A mediocre amateur listening to the overture of "Der Freischütz" at the Conservatory would be shocked, no doubt, if the horn should, by one of those accidents which it is impossible always to avoid, be out of tune; but the same amateur after having heard this same piece executed by a second-rate orchestra would be very well satisfied with the concert, and would take into account neither the false notes which might have escaped nor the want of regard to time or expression, and if he does not place the two orchestras on the same level, it will be from personal feelings. Among the crowds which visit the galleries of the Louvre every year, how many people prefer a common and inharmonious picture blazing with colour to a master-piece of Titian!

A person who sings falsely is said to have "no ear," and often, in fact, it is to the want of exactness in the ear that the faults in the voice are due. In this case the evil is beyond remedy, the musician who has an incorrect ear can never be sure of producing correct sounds. But if the falsity of the note is due solely to an imperfection in the vocal organ, a man who cannot sing correctly, can play the violin or violincello perfectly, because his ear judges correctly of the sounds which he produces from his instrument.

Intensity, distance, and direction of sounds.—As we have seen, authors do not agree upon the functions of the different parts of the auditory apparatus in the perception of the intensity, the distance, and the direction of sound. The perception of the intensity of sound seems to depend more on the relative perfection of the whole organ than on any one of its parts. Vibrations are transmitted to every part of the ear, and even to the whole body, in loud noises and sounds. Thus thunder, the report of cannon, the grave notes of an organ or of a double-bass viol, cause a tremor in the whole body; but it is by the vibratory excitement of the auditory nerve that we judge of the intensity of sounds, as the optic nerve enables us to appreciate that of light.

In regard to distance, if it is a sound with which we are familiar, that of the human voice, for example, we judge of

it by the greater or less force of the auditory impression. As for noises of which we do not know the intensity at a given distance, as thunder, we estimate it in the same way, but with less certainty according as it is faint or loud.

It is therefore to reasoning, founded on the sensation, that we owe the ability to judge of the distance as well as the intensity of sounds, and it is the same as to their direction. When we hear a sound more distinctly with one ear than with the other, we judge that it comes from the side on which the impression is strongest, and the ability of the organ to seize slight degrees in the intensity enables us to tell in what position of the head the sound is most clearly perceived. We are therefore led to place it in a certain position in regard to the direction, and by this means we acquire an idea of it within certain limits. Hence, if the ears are both in the same situation relative to the sound, as when it is in front of or behind us for example, we find it impossible to distinguish in which direction it is without turning the head.

This uncertainty which we always feel in regard to the exact distance and direction of sounds enables the ventriloquist to produce what are wrongly supposed to be illusions of hearing, but which are simply errors of judgment guided by the imagination. The hollow, feeble voice of the ventriloquist seems to come from a great distance, from above or from a certain depth below us, the sense of the words, the expression of the voice, the varied tones and mimicry of the juggler, do the rest.

Duration of auditory impressions.—Savart has demonstrated that the duration of acoustic impressions is about the tenth of a second. Thus when the vibrations of a body do not exceed nine in a second, the ear perceives a series of distinct impressions, but beyond ten or twelve the sensation becomes continuous.

Sensations of internal origin.—As the eye may be the seat of luminous impressions produced by other means than light, so sounds and noises may be heard, without the ears having been excited by sonorous waves. Ringing and humming sensations may be produced in or imparted to them, under

abnormal conditions into which we shall not inquire; and of which the mechanism is obscure or unknown. A prolonged shock to the auditory nerve by a loud sound or noise will cause a persistent confused sensation, which is felt by everyone after a long journey by railway, or after being near a great waterfall or in a mill for a length of time.

Parallel between the ear and the eye.—The eye and the ear present many analogies, both in regard to their functions and their anatomy. The pavilion of the ear has been compared to the eyelids, the auditory canal to the anterior chamber of the eye, the tympanum to the iris, the cavity of the tympanum to the posterior chamber, the small bones to the crystalline, and the liquor Cotunnii to the vitreous body. These organs differ in their nature, like the exciting agents which pass through them. Sound and light both originate in vibrations, but transparency is the essential condition of the organ through which light passes, while sounds are propagated through all bodies, solid, fluid, or gaseous.

The sense of light enables man to contemplate the admirable spectacle of the universe, but for the eye nature is mute; to it motion alone denotes life; hearing completes our impressions, everything is animated by it, and man takes part in the life of the external world, and shares the thoughts of his fellows. The perfection of these two senses enables us the better to appreciate the connection between the functions, and the unity of our organs. The sight speaks more directly to the intelligence, it enlarges the field of thought, it gives birth to precise notions of light, of form, of extent; and it permits the communication of thought by conventional signs. Hearing is a necessary condition of articulate language; without it man lives alone, affection and confidence lose their most precious forms of expression, and friendship cannot exist.

Auditory sensations act upon the nervous system with more force than visual sensations. We are carried away by rhythm, or it adapts itself to our ideas and our passions; music plunges us into an ideal world, and holds us by an indefinable charm; in a word, if sight speaks more especially to the intellect, hearing addresses itself to the affections.

Sight is certainly more necessary to man than hearing, but still the blind are generally gay and communicative, while the deaf seem inclined to melancholy. As to the relative influence of these two senses on the development of the intellect, we know that the education of the deaf is slow but may be complete, while that of the blind is, on the contrary, rather rapid, but is almost always very limited; many ideas cannot be acquired by them, and, as has been remarked by M. Longet, their minds rarely attain maturity.

CHAPTER XIII.

Sense of smell. Olfactory organs.—Nose; nasal fossæ, turbinated bones, pituitary membrane.—Olfactory nerve.—Odoriferous principles; their development, their action on the nervous system.—Smell,—its seat; duration of olfactory impressions.—Uses, and acuteness of smell.

Olfactory organs.—The smelling apparatus is situated in the middle of the face, between the orbital cavities and the palatine arch. Placed thus above the organ of taste, which it resembles in many respects, it forms the entrance to the respiratory passages, and controls to a certain extent the purity of the air which enters them. It is composed of the nose and the nasal fossæ.

The nose.—Two thin, flattened bones, slightly curved in their breadth, form the superior portion of the nose. They are articulated by their internal border in the median line; at their external border they are united to the ascending processes of the upper jaw, and they are attached at the root of the nose by sutures to the frontal bone. Their inferior borders are attached to the cartilages which complete the nasal walls. The arch formed by the nasal bones is supported by a bony partition, to which is attached a cartilaginous plate, which divides the nasal cavity into two symmetrical halves, and separates the nostrils. A delicate skin envelops the nose and covers its little muscles, which are more important from a physiognomical point of view than from their organic functions.

Nasal fossæ.—This is the name applied to two irregular cavities which are continuous with the nasal cavities; they rest against each other on the median line, and are bounded below by the palatine arch, and above by the cribriform

plate (*cribrum*, a sieve, being perforated with numerous holes) of the ethmoid bone. They open posteriorly just above the throat. A partition formed by the perpendicular plate of the ethmoid, the vomer (*a ploughshare*), and a cartilage separates the nasal fossæ on the median line; the prolongation of this cartilage separates the nasal cavity into two parts, as we have already seen. On the external walls of the nasal fossæ there are bony folds, which are called *upper*, *middle*, and *lower spongy bones*, and are separated from each other by corresponding passages. The nasal fossæ communicate with numerous sinuses in the substance of the bones of the face and skull.

The whole internal surface of the olfactory apparatus is lined with a mucous membrane called the *pituitary membrane*, this is the immediate organ of smell. This membrane dips into the numerous inequalities of the spongy bones and the passages, thus presenting a larger surface to olfactory impressions. The *olfactory nerve* is ramified in the pituitary membrane. It penetrates the nasal fossæ through the cribriform plate of the ethmoid, but is distributed over the upper portion only. In the lower portion of the fossæ the pituitary membrane receives only nervous filaments from the fifth pair, a circumstance to be noted in reference to the mechanism and seat of smell.

Odours.—The philosopher calculates the velocity and intensity of light, he can analyze it, he knows from what substance a given colour emanates, and if this substance exists in the star, the rays of which he is observing; he demonstrates in the vibrations of bodies the origin of the sonorous waves, and sees in light as in sound, not particles of matter traversing space, but a movement excited in the surrounding media. Some learned men have thought that odours also result from a vibratory movement transmitted to the ambient air by the molecules of odoriferous substances, but Fourcroy demonstrated the origin of odoriferous emanations in the volatility of the immediate materials of vegetables; and odours are now generally considered as bodies existing by themselves, and not as a purely physical result comparable to sonorous or luminous waves; they are extremely minute

material particles, volatilized in the atmosphere. But here matter seems to become intangible. The chemist can extract from a body the essential oil which gives it its odour, but he cannot separate the odoriferous principle from the oil itself, and he can only recognize its presence by the special impression received by the olfactory nerve.

Nothing gives us a more exact idea of the divisibility of matter than the diffusion of odours. Three-quarters of a grain of musk placed in a room cause a very powerful smell for a considerable length of time without any sensible diminution in weight, and the box in which musk has been placed retains the perfume for an almost indefinite period. Haller relates that some papers which had been perfumed by a grain of ambergris, were still very odoriferous after a lapse of forty years.

Odours are transported by the air to a considerable distance. A dog recognizes his master's approach by smell even when he is far away; and we are assured by navigators that the winds bring the delicious odours of the balmy forests of Ceylon to a distance of ten leagues from the coast.

Simple experiments prove that odoriferous bodies emit a stream of particles so small as to seem to be immaterial. When a morsel of camphor or a small body saturated with ether, or minute portions of benzoic acid, are thrown upon water, they are animated by a peculiar movement, which is due to the propulsion produced by the invisible vapour which emanates from these substances.

Heat, light, and other influences modify the production of odours, and their transmission in space. Certain plants are odoriferous only at night, and it is especially in the morning and evening, when the dew is scanty, that flower-gardens perfume the atmosphere. Rain destroys the perfume of flowers, probably by its mechanical action, and by lowering their temperature. It is remarkable also that animal or vegetable odours are feebler, as the countries are colder in which the plants or animals live from which they emanate. Hence perfumes come principally from tropical countries.

It has been stated that substances absorb and retain odours according to their colour. Thus, the experiments of Stark

tend to prove that black garments are more quickly impregnated with an odour, and retain it longer, than light-coloured garments. On the other hand, A. Duméril assures us he has ascertained that white stuffs absorb odours as quickly as others, but that the odoriferous particles are sooner evaporated from them. There must consequently be in this respect a difference in odours like that in luminous rays, but the first of these phenomena has not been at all so clearly demonstrated as the latter.

Under the influence of a shock, or from friction, certain vegetable and mineral bodies emit odours more or less powerful. Such are several varieties of wood, especially lilac and Saint Lucy, the leaves of mint, lemon verbena, and southernwood, and certain calcareous or silicious rocks. Other plants, on the contrary, lose their aroma on being bruised, like the mignonette, the violet, &c. The contact of water, or of vapour, also develops odours in argillaceous rocks and several vegetable substances.

Odours have a very marked effect on the nervous system; but some persons are far more impressible in this respect than others. There is no doubt that certain odours may cause grave disturbance in the nervous system; but the imagination sometimes plays a prominent part in the discomfort produced by a bouquet of roses or violets; the sight of artificial flowers is sometimes sufficient to excite persons painfully who believe them to be natural. People often ascribe to this influence of odours on the brain, what is really due to the effects of carbonic acid gas, or of poisonous emanations absorbed by the lungs; and how many persons there are who believe the open combustion of charcoal is innocuous, because it does not emit so much smell as coal.

But even after making due allowance for the effects of the imagination, it is certain that odours act as an excitant on the brain, which may be dangerous when long continued. They are especially dreaded by the Roman women. It is well known that in ancient times the women of Rome indulged in a most immoderate use of baths and perfumes; but those of our times have nothing in common with them in this respect; and the words of a lady are quoted, who said on

admiring an artificial rose, "It is all the more beautiful that it has no smell."

We are warned by the proverb not to discuss colours or tastes, and we may add odours also. Men and nations differ singularly in this respect. The Laplander and the Esquimaux find the smell of fish-oil delicious. Wrangel says his compatriots, the Russians, are very fond of the odour of pickled cabbage, which forms an important part of their food; and assafœtida is, it is said, used as a condiment in Persia, and, in spite of its name, there are persons who do not find its odour disagreeable any more than that of valerian.

Smell.—The air which enters the organ of smell deposits on the surface of the pituitary membrane the odoriferous principles with which it is charged, it becomes impregnated with them, and it is in its tissues that these principles come in contact with the terminal fibres of the olfactory nerve. We have already stated that this nerve is only distributed over the upper portion of the nasal fossæ; in order to produce the sensation of odours, therefore, the air inspired must reach not only the inferior but also the superior parts of these cavities. The nose is contracted at the root like a funnel, and tends to guide the odoriferous effluvia towards the point where the impression is to be perceived; and the stronger the inspiration the higher up the column of air is carried, and the more it excites the filaments of the special nerve. Some physiologists have thought, with Magendie, that the nerves of the fifth pair, which ramify over the lower portion of the pituitary membrane, were designed to serve the purpose of smell; it seems to be clearly demonstrated that the sensations caused by acid or ammoniacal vapours are not olfactory, but simply painful.

The pituitary membrane in its normal condition is constantly humid, and the secretion with which it is bathed is one of the indispensable conditions of the function of smell; and, therefore, we remark at the commencement of a cold in the head, when this membrane becomes dry, that the sense of smell is more or less impaired. The nose, by shielding the membrane from the immediate contact of the air, preserves its functions, and the loss of this organ diminishes,

or even completely destroys, the sense of smell. Smelling is ordinarily involuntary, but it may be rendered more active by the exertion of the will. The inspirations are then stronger and more frequent, in order that the odour which we wish to perceive or enjoy may be carried in greater quantity toward the nasal arch. But if, on the contrary, we wish to avoid a disagreeable odour, a sudden expiration takes place from the nose, and we breathe instinctively through the mouth, and the soft palate closes the olfactory cavities behind. It is in this way that we are able to diminish the disagreeable impression arising from the odour in drinking sulphureous waters.

Whether odours reach the seat of smell by the nose, or through the posterior opening of the nasal fossæ, the result is the same; it is by this means that we perceive the aroma of the food when eating with the mouth shut; but under these latter conditions the persistence of the impressions very soon blunts the sensibility. A man fasting immediately perceives it, if a man with whom he is speaking has taken the smallest quantity of alcohol, even though it was only a glass of red wine; after eating we distinguish much less easily in others the odour of the aliments of which we ourselves have partaken, and the odoriferous principles of which have already saturated the olfactory membrane.

The sinuses of the bones of the skull and of the face, which are in communication with the nasal fossæ, take no part in the perception of odours. It has been thought that they may contribute by their secretions to moisten the pituitary membrane, or serve as receptacles for the air, which is afterward carried from their cavities to the organ of smell.

Duration of olfactory impressions.—When we have inspired a strong and penetrating odour, the sensation is prolonged for a certain time, sometimes for several hours. It is probable that in this case the impression is not single, but is incessantly renewed by the odoriferous particles with which the mucus of the pituitary membrane is impregnated, or which is confined in the air in the sinuses. Sometimes also the odour has penetrated the garments, or is attached to the skin or the hair, and from thence continues its impressions.

Any vigorous exercise, or eating, by exciting the secretions, generally causes the sensation to disappear, the persistence of which might be exceedingly inconvenient.

Gerdy makes the sense of smell the counsellor of the stomach. When the appetite is excited the smell of food is agreeable; but it is repugnant, on the contrary, when hunger is appeased, and the sense of smell warns us to take no more food. We may say, with reason perhaps, that this sense completes that of taste, by enabling us to appreciate the aroma, without which food and drink would cause only a gross sensation, or one at least entirely devoid of all delicacy. When the sense of smell is lost, or even enfeebled, the taste, perceiving flavours only, seems almost extinguished, existing alone.

The sense of smell is very unequally developed in individuals, but it is said to be of extreme delicacy in some races of men, and especially among savages. The stories recounted of individuals following game by tracking, and of negroes who could distinguish by smell the tracks of a negro from those of a white man, seem to indicate a faculty quite as nearly related to the sense of sight as to the one under consideration; and it must be admitted also that individual experience and careful attention to particular circumstances produce the same results when applied to the sense of smell, as to sight or to hearing.

CHAPTER XIV.

Sense of taste.—Organ of taste.—Special nerves of the organ.—Flavours.—Taste.

Organ of taste.—In describing the mouth as a part of the digestive apparatus, the functions of its several parts were explained, as well as of the organs which surround or fill its cavity. It is only requisite here to repeat that the tongue receives three nerves, of which one, the great hypoglossal, gives it motion; and the two others, the lingual and the glosso-pharyngeal, give it gustatory sensibility. The tongue participates by its movements in the digestive functions, and in the articulation of sounds; but it has besides a special sensibility—it is the principal organ of taste.

Flavours, taste.—The cause and intimate nature of tastes are no better understood than those of odours. It is by volatilization that the intangible particles of the odoriferous principles reach us; it is by a solution more or less complete that substances impart their flavour, that inherent property which taste alone reveals to us. We recognize in this way their acidity or saltness, whether they are sweet or bitter, &c.; but nothing in the nature of bodies, in their texture, or in their constituent elements, has ever yet explained their sapidity. Flavours elude analysis and defy classification, even that which divides them into *agreeable* and *disagreeable*, for the taste of individuals and of nations singularly differs in this respect. The Laplander and the Esquimaux drink great quantities of train-oil, which for them is a greatly esteemed article of food, and is most admirably adapted to the exigencies of a Polar climate; the Abyssinians eat raw flesh, and find its flavour excellent, while the inhabitant of the West

partakes of it with the greatest repugnance, and only as a medicine. Oysters, which are so generally esteemed in our country, are to some persons disagreeable and nauseous; and truffles, the delight of the gourmand, are rejected by the uninitiated on account of their flavour and their perfume. It is the same with almost all alimentary substances; they are eagerly sought after by some, and despised or abhorred by others. Let us remember the proverb, and not dispute in regard to tastes; each is suited to its own country, and goodly numbers acclimatize themselves, to the great advantage of peoples, among whom at first they seem exceedingly strange. Man should control his taste, and habituate it to all wholesome aliment; this neither excludes choice, nor blunts the delicacy of the sense; and while we resist its seductions, we should give timely heed to its instincts and its counsels, for they are often invaluable.

Among the substances which we taste, there are few which address themselves solely to that sense, and not at the same time to the sense of smell. This mingling together in the same substance of flavours and odours, and the simultaneous action of the senses which perceive them, has induced some authors to consider them as forming but one. They are, notwithstanding, quite distinct in their seat and in their function; the mixed sensation resulting from the union of their impressions differs entirely from that which they cause singly; we may say that the sense of smell is the necessary complement of taste, for the latter is reduced to very trifling importance when it acts alone.

However much flavours may vary, they are all referable to a very few types, to the mixtures and shades of which we are quite indifferent when they do not offend us. The taste solely judges whether a substance is salt or sweet, acid or astringent, and so forth; but when our food does not awaken any other sensations, we are tempted, in spite of its flavour, to pronounce it insipid; vanilla cream and coffee cream, or ices with rum or with maraschino, do not differ in taste when the nostrils are closed. If, instead of olive oil and wine-vinegar, bleached oil and acetic acid diluted with water be used to season a salad, we shall have the sensation of taste without

that of smell. We must not then confound with natural taste that which smell adds to it, and it is to supply the lack in this respect of what is wanting in our food and in our blunted senses that we make use of condiments.

We must also distinguish the bodies the action of which is confined to the sense of touch exercised by the tongue, and many impressions reputed to be those of taste ought rather to be considered as purely tactile, such as astringency, tartness, the irritating or caustic action of certain substances, &c.

On this principle M. Chevreul has divided substances into four classes according to the impression which they produce in the mouth: 1st, bodies acting on the sense of touch in the tongue, such as rock-crystal, ice, and so forth; 2d, bodies acting on the sense of touch and of smell, such as aromatic metals, tin and copper for example; 3d, bodies acting upon feeling and taste, as sugar-candy, common salt, &c.; 4th, bodies acting on the touch, taste, and smell, as mint-lozenges, chocolate, or volatile oils.

All alimentary substances figure necessarily in the latter class.

Authors do not agree upon the seat of taste; several believe it extends over nearly the whole surface of the tongue, to the pillars of the fauces, and to the upper surface of the soft palate, to the tonsils, and to the pharynx. It is now generally believed to be located at the tip, at the base, and on the edges of the tongue, and at a certain limited space on the anterior surface of the soft palate. According to M. Longet, the back of the tongue and the pillars of the fauces are not entirely destitute of gustatory sensibility.

Savoury substances do not produce the same impression upon all parts of the tongue, many salts on the tip of the tongue have an acid, salt, sharp, or styptic, at the base a bitter or metallic taste; others, on the contrary, have the same flavour on every part. In general, acidity is best perceived at the tip, and on the edges of the tongue, saline or metallic flavours are developed at the posterior portion.

In order to perceive the flavour, the savoury molecules must be bathed in saliva, and partially dissolved, so as to be

placed in more immediate contact with the surface of the tongue. To further insure this contact, the tongue applies itself to the palatine arch, and presses the food against its surface. It is then that the gustatory impression is produced in its full force, and from this it has been inferred that the palate is the principal seat of taste. The action of the palate, however, is purely mechanical, and is limited, as we have stated, to securing immediate contact between the savoury bodies and the tongue. This is demonstrated by covering the palatine arch with a thin pellicle which is itself insipid and impermeable; the taste is just as acute under these conditions, but if the tongue is covered with this same pellicle, and the palate uncovered, no taste is perceived. The cheeks and lips also contribute to taste by carrying the particles of food which may have fallen outside the dental arch during mastication back to the tongue. Taste acts not less delicately in deglutition, when the contents of the mouth descend between the base of the tongue and the soft palate on its way through the throat. Food and drink must remain for a certain time in the mouth in order that their full flavour may be perceived; thus the gourmand takes care to retain them, and exhaust, as it were, their aromas, before sending them to the stomach. For this reason, also, wine-tasters hold the wine in their mouth when they wish to judge of its quality, but they avoid swallowing this mouthful of wine after it is thus robbed of its bouquet; they reject it after thoroughly moistening the surface of the tongue, and they can then decide as to the vineyard and the year of the vintage. If they drank the wine which they taste, the smell, which here plays the principal part, would very soon become dulled.

The papillæ of the tongue, it is generally considered, are endowed with gustatory sensibility, and this sensibility is principally attributed to the fungiform papillæ. According to M. Longet they are rather tactile organs, and the learned physiologist supports his opinion by the fact that, on the point of the tongue the taste is no less perfect where the parts are destitute of papillæ, while the feeling there is much less delicate than on the papillæ themselves.

The impressions of taste are quite persistent according to some authors, but this persistence is due to the presence of savoury particles on the tongue, and is more correctly the constant renewal of the impression. Experience shows how difficult it is to get rid of certain flavours, and it is easy to understand that when dissolved, and retained by the saliva in what may be called the papillary fleece of the tongue, the particles remain, and furnish for a considerable time the materials for the sensation. It is a mechanism analogous to that which produces the persistent smell of creosote and dextrine from the hands several hours after contact with the disgusting perfume.

Taste is but slightly developed in infancy, and, although it acquires some delicacy in youth, it is especially in mature age that it reaches its perfection. Far from growing feeble with the lapse of years, it retains all its acuteness, and consoles the aged for the irreparable injuries of time. It is perfected by exercise, and attains in some individuals remarkable delicacy, as in professional tasters, for example; but the prolonged use of highly seasoned food, the abuse of alcoholic liquors, and above all of tobacco, enfeebles and blunts it in what may be termed its olfactory portion.

The question has been raised whether taste is developed by civilization. This is admitted by several physiologists, but perhaps it would be necessary to establish a distinction between the natural sensibility of the organ and its aptitude in judging of a great number of flavours. In this last respect there is no doubt of the superiority of civilized nations, but there is great difference between them notwithstanding, and if we were to measure the civilization of nations by the delicacy of their taste, we might arrive at very flattering conclusions for some, it is true, but at very painful ones for many others. We will content ourselves with saying that, in Europe, the taste is generally more developed in the south than in the north. In conclusion, it furnishes very little material to the intellect. Its scientific use is limited to indicating to the chemist the sapidity and species of flavour of substances.

Its functions, in relation to nutrition, dispose to gaiety and

good humour, and nothing except labour produces a more powerful diversion for the mind of a person a prey to chagrin or melancholy. Stationed at the entrance to the digestive passages, it guides us in the choice of food, and controls its nature and quality; it warns us against repletion by its indifference to the flavours the most appreciated at the beginning of the repast, and compensates by agreeable sensations for hunger—the hard necessity of our organization.

Taste is therefore a useful servant, but on the whole we see that of all our senses, it is not the farthest removed from matter, and what is worse still, it has much to be pardoned for. The stomach reproaches it with not being so virtuous as physiologists seem to believe, and accuses it of being dangerously seductive, and the worst enemy of those who should regulate their diet; and though it sometimes gives timely warning by disgust, it is often in the wrong in rejecting wholesome food under the pretext that it is new or that its prejudices condemn it. The taste retorts by throwing the blame on those who have taught it to be fastidious; it professes, and with truth, to be docile to training, and that the prejudices come from the master of the house; and it adds that, though perfectly competent to judge of the merits of a cook, it is very little acquainted with questions of hygiene, and that the enemy of the stomach is gluttony and not taste.

Some persons affect a contempt for this sense, explicable, no doubt to a certain extent, but which tempts us to believe that they speak of it only from hearsay. "The mind should take precedence of the body," as Belisus emphatically declares; but the good Chrysalus, was he wrong in saying, "Yes! my body is myself, and I will take care of it?" May we not remember in proper time and place that "man lives on good soup, and not on fine words:" besides, one does no harm to the other, and to want even the most modest sense is to be imperfect after all. Thénard, speaking of cooking before a crowded audience at the Sorbonne, called it "that important part of chemistry."

We may think what we please of the taste, but it has always in all ages been the endowment of men of genius.

In reading Brillat-Savarin, we feel disposed to believe that the mind and the gastronomic senses are inseparable. But these are delicate questions; and as we would not toss an apple of discord between nations, neither shall we between individuals, but rather prudently refer the reader to the *Physiology of Taste.*

CHAPTER XV.

Sense of touch.—Difference between touch and feeling.—Tactile sensibility and general sensibility.—Organ of touch. Sensation of contact; difference in the sensibility of different regions of the body; simple contact, shock, vibration.—Sensation of pressure; relative aptitude of different regions in appreciating it: variable sensation according to the form of the body and the extent of its surface.—Sensation of temperature, variable according to the temperature of the skin, the density of bodies, and the surface in contact: identical sensation from contact with a body very hot and very cold; relative sensibility of different regions to temperature.—The touch; its delicacy.—The touch compared with the other senses; illusions of touch; persistence of tactile impressions, sensations from internal or subjective causes; causes which modify feeling.

Touch and feeling.—Tactile sensations, like all others, are more or less complete according as the attention is, or is not, directed to them. The contact of a foreign body with any sensitive portion of the organism is revealed to us by *feeling*, and it is by *touch* that we discover the form, resistance, and temperature of this body. Feeling may be involuntary, touch is an act of the will; there is therefore the same difference between feeling and touch that there is between seeing and looking, between hearing and listening, scenting an odour and smelling it, perceiving a flavour and tasting it.

We must also distinguish between impressions due to general sensibility and tactile sensations proper; thus, if we knock the elbow we feel an acute pain along the course of the ulnar nerve, but the impression produced on the skin is perfectly distinct from this deeper suffering when not entirely masked by it. It is the same in sensations resulting from a shock to the right hypochonder which produces a pain in the liver. All the tissues which receive nerves of sensation may

be the seat of impressions which may be referred to the general sensibility, and which are for the most part painful: impressions on the sense of touch are only produced in certain tissues specially endowed with this sense. General and tactile sensibility are independent of each other, and they are not developed proportionally; as, for instance, the palmar surface of the fingers is endowed with an exquisite sense of feeling, but it is almost insensible to a blow which would be very painful to the cheek, in which this sense is much less developed.

Organ of touch.—Touch has its seat in the skin throughout its whole extent, and in some of the mucous membranes. It is by the nervous papillæ containing the tactile corpuscles that the impression is perceived, and the tactile sensibility of any region is in proportion to the number of nervous papillæ existing in it.

We receive three distinct impressions at a time by the sense of touch—that of contact from a foreign body, that of the pressure which it exercises on the skin, and that of its relative temperature.

The *sensation* of *contact* is not equally distinct and precise in all parts of the body, and the reason of this we will endeavour to explain. If we apply simultaneously the two points of a compass to the skin, they must be more or less separated according to the region experimented on, in order that their contact may cause one or two distinct sensations, and we may in this way measure the delicacy of the sense at any given point on the skin. It is evident that the less sensitive the skin is, the more widely we must separate the points of the compass to produce a double sensation. E. Weber after many experiments classes the regions in the order of their sensibility as follows:—The tip of the tongue gives a double sensation when the feet of the compass are separated about half a line; the palmar surface of the ends of the fingers, one line; the red surface of the lips and the surface of the second joint of the fingers, two lines; the end of the nose and the palm of the hand near the fingers, three lines; the back and edges of the tongue at about an inch from the tip, and the skin of the lips, four lines; the palm

of the hand, the cheek, and the eyelids, five lines; the palate, six lines; the prominence of the cheek, and the sole of the foot near the great toe, seven lines; the back of the hand near the fingers, eight lines; the gums, nine lines; the lower portion of the forehead, ten lines; the lower part of the occiput, twelve lines; the back of the hand, fourteen lines; the throat under the jaw, fifteen lines; the shoulder, fore-arm, and knee, eighteen lines; the chest over the sternum, twenty lines; the loins, the upper part of the back, and the neck on the line of the spine, twenty-four lines; the middle of the back, of the neck, of the arm, and of the thigh, thirty lines.

Gratiolet found by oft-repeated experiments that the distances recognized by the pulp of the fingers might be very much less. By touching two points on the same papillary ridge on the pulp of the last joint of the middle finger, separated only by the orifice of a sudoriferous duct, the two sensations were plainly distinguished at the distance of less than one quarter of a line.

The experiments of Valentin, on the other hand, prove that tactile sensibility varies from single to double in corresponding regions in different individuals; we can only accept the measurements of Weber, therefore, as indicating the relative sensibility. And lastly, we are indebted to M. Belfield-Lefèvre for the experiments which led him to the following conclusions. The distance between two points of contact is better appreciated, if these points are placed on a line transverse to the axis of the body, than when on a line parallel to it or longitudinal. According to Weber, on the ends of the fingers, and on the tip of the tongue, the distance is better appreciated on a longitudinal than on a transverse line. The distance between two points of contact, distinct and simultaneous, is greater in proportion to the delicacy of feeling in the region experimented on; it seems to be greater also when the contact takes place *successively* in the two points, than when it takes place simultaneously, and greater also if the two contacts are separated by a longer interval of time. If the two points of contact are separated by the median line, the distance between them seems greater than

if they are placed on the same side of the body.—If two points are touched, which are subject to variation from functional displacement, the eyelids or the lips for example, the distance is greater than if the two contacts take place on one eyelid, or one lip.—This sense is also increasingly developed on the surface of the limbs in proportion to the distance from the body.

The sensation of contact varies according as it results from a simple application of a foreign body to the skin, or from a shock, or a succession of shocks repeated at short intervals, like that which produces vibration in a body. In the latter case the region of contact receives a shock in proportion to the intensity of the vibrations; as when we touch the skin with a tuning instrument while vibrating, or if we grasp a vibrating metallic body or wooden rod, or close the lips against the reed of a basoon while it is being blown into, it produces on the surface in contact an impression, varying from a painful shock to a simple tickling or pleasurable sensation. It is a sensation of the same nature, though diffused through the whole body, that we feel from the vibrations impressed on the atmosphere by the explosion of artillery, the roll of thunder, or the ringing of a great bell. The sense of touch then gives us an idea of the sonorous waves which excite the auditory nerve, and furnishes us with the proof that the same cause acts differently on the special nerves of the different senses. In fact, the nervous papillæ of touch transmit a sensation of motion and of shock: the tympanum perceives neither tickling nor shock, the impression which it transmits to the auditory nerve is not that of a vibratory movement, but of the sound which results from it.

The *sensation* of *pressure* is distinctly perceived by touch: but we must distinguish between the pressure of a body against the skin, and the resistance which this body offers to a muscular effort tending to displace it. If when the hand is supported, and a weight placed in it, no effort is made to raise it, and the muscles remain inactive, we feel a sensation of pressure, the force of which may be judged of with more or less exactness; but the moment we endeavour to appreciate the weight the sensation becomes complex, and we

have the idea of pressure, and that of the muscular effort which we oppose to it; and great attention is necessary to prevent an instinctive contraction of the muscles of the hand to resist the weight with which it is charged. We must also take into account habit and the relative strength of the hands; as the right, which is generally more used than the left; may be less sensitive to pressure, and appreciate its degree less exactly.

Those portions of the skin where the touch is most acute, and where two points of contact are perceptible at slight distances, are, according to Belfield-Lefèvre, those which estimate most correctly the degree of pressure; as the lips, the palmar surface of the fingers, the under surface of the toes, and the skin of the forehead, are better endowed in this respect than the rest of the body. But neither touch nor pressure alone can give an exact notion of the weight, we must support the body on which the experiment is made by muscular effort; the inequality of the two hands in this respect is so well known, that we use one and the other alternately in order to ascertain correctly the weight of the object. It is estimated that pressure alone will not enable us to appreciate more than an eighth of difference between two weights, but by lifting we can appreciate a sixteenth.

The form of bodies also influences the sensation of pressure; when an object with only a small surface is applied to the skin the pressure seems greater than when it is spread over a greater extent; and it may even become painful when supported on a restricted point; thus, the weight which we carry with ease on the whole breadth of the shoulder, is intolerable when resting only on one of its angles. A truncated cone laid on the forehead seems heavy or light according as it rests on its smaller or larger base. Soldiers and travellers know very well that they cannot with impunity exchange the broad bands of their knapsacks for narrow straps or cords. It is unnecessary to remark, that if the weight be distributed over a large surface, each point of that surface supports but a fraction of the entire weight; the whole mass, on the contrary, presses on a limited space.

Sensation of temperature.—We recognize by contact with a

body whether its temperature is the same, or whether it is higher or lower than the point of skin which touches it; in other words, touch gives us an idea of the relative temperature of bodies. But the sensation may change in a few moments, as the object in contact with the skin rapidly imparts or borrows heat; and if it is warmer or colder than the skin, an equilibrium is soon established when the difference is inconsiderable. And the same body may produce a sensation of cold or heat successively without change of temperature, according as the surface of the skin at the moment of contact is warm or cold; thus, if we take a bath in water cooler than the air, the temperature of the air, which seemed low on entering the bath, appears warm when we come out a few minutes after. It is for the same reason that we find the air of a cellar cool in summer, and warm in winter, although it has not varied.

The sensation is marked in proportion to the conducting quality of the object in contact with the skin. Air seems warmer than water at the same temperature, because the air being a worse conductor of heat takes less from the skin in a given time. Air in motion, by exciting evaporation, causes a very sensible loss of heat, as every one knows; and the atmosphere also, which seems very cold when the wind blows, grows warmer apparently when the wind ceases, or when we are sheltered from it.

The contrary effect from that caused by pressure is here seen; the sensation is marked in proportion to the extent of surface. The whole hand appreciates the temperature better than a single finger; and a body of a given temperature, applied over a large surface, will give a sensation of more intense heat than a warmer body which touches only a small portion of skin. We can easily understand that the skin absorbs in a given time more heat by a surface four inches square, than by one only one inch square, and the impression transmitted to the brain in this experiment represents rather the sum of the heat absorbed from all parts of the surface in contact, than the temperature of the body with which the experiment is made.

When we touch a body of a lower temperature, the same

sensation is produced as when we touch one at a high temperature. Contact with a ball of frozen mercury causes a burning sensation, the same as that of iron heated to 100° C. (212° F.), though we know that mercury freezes at —40° C. (—40° F.) Voyagers in the Polar regions are compelled to envelop the metallic portions of their instruments in non-conducting substances, so as to be able to handle them with impunity.

The skin and the mucous membranes do not appreciate differences of temperature with equal nicety in every portion of their surface, and the regions which are most sensitive to contact are not those which best indicate the temperature. The palmar surface of the fingers, the tongue, and the lips, are less impressionable in this respect than the skin of the cheeks, eyelids, elbow, and the pituitary membrane. We may perhaps attribute this relative insensibility in the hand, and the mucous membrane of the cheeks, to the habit of contact with warm bodies. The hand becomes rapidly inured to hold objects hot enough to cause a painful sensation to persons unaccustomed to it. We see this in chemists, blacksmiths, and others. The skin need not necessarily be thickened, although this condition also decreases the sensibility. We often see persons of mature age bear without pain the contact of food so hot that younger people could not swallow it. The mucous membranes of the œsophagus and the stomach are more sensitive in this respect than that of the mouth; but when the food is held immovable for a few seconds between the palate and the tongue, the heat is absorbed, and the food or drink may be swallowed with impunity.

It is clear from the preceding remarks that the sense of touch is an unreliable thermometer; it is sufficient, however, to guide us in matters relating to health, and in regard to external objects, especially when we permit its full development by touch.

The hand is the principal means of exercising the *touch*. The organization of this admirable instrument, its numerous articulations, the freedom and variety of its movements, the tactile sensibility which is so fully developed in the palmar

surface of the fingers enables us to obtain, by means of it, ideas of the form and relative situation of objects, of their motion, their resistance, their weight, their solid or fluid condition, of their temperature, &c. The hand grasps objects, moves over their surface, follows their outline, measures their distance and their extent, as far as the length of the lever of which it forms the extremity will permit. By the aid of this lever it raises bodies, estimates their weight, their firmness, and their elasticity. In touching them with the end of the fingers it perceives the details of their form and their relative value. We have seen of how great importance delicacy of touch is to the artist, it is no less precious to the physician, and it renders him service which he asks in vain of any other sense. It is by the touch that he arrives at a knowledge of the state of the circulation, the existence of fluids in the tissues, and their normal or morbid consistence.

By exercise the touch attains extreme delicacy. The blind learn to read with facility from letters printed in relief, and to execute certain work with tools. Saunderson, professor of mathematics in the university of Cambridge, was blind from his cradle, but he had attained to such exquisite perfection of touch, that in a set of medals he could distinguish the genuine from the counterfeit pieces, though the latter were so well executed as to deceive a connoisseur judging by sight. He felt, by the impression of the air on his face, when he was passing near a tree. It is said that Jean Gonnelli, a blind sculptor, could model in clay an exact copy of a statue the outline of which he had studied by touch, but doubtless we must take this anecdote with some allowance for exaggeration.

However this may be, the touch has been from the earliest antiquity an object of the most enthusiastic admiration to naturalists. It has been considered as the most exact and the most infallible of the senses, able to control their testimony and rectify their errors. It has been placed in the front rank, and held up as a type of which the others are only the modifications. Buffon says, "It is by the touch alone that we acquire complete and accurate knowledge: it is this sense which rectifies all the other senses, which might only delude

us and make us err, if it did not guide our judgment." But Buffon thought that "the difference between our senses results only from the more or less external position of the nerves, and from their greater or less number in the parts which constitute the organs." The illustrious naturalist did not recognize the special functions of the sensitive nerves; the sensations of colours, of odours, of flavours, and of sounds, were for him only tactile impressions. How could we admit that feeling could guide us in judging of the colour of objects, of their taste, their odour, or their sound! Even while admitting that we can compare the excitation of the skin by contact to that of the retina by the luminous waves, it is not the less impossible to establish the least analogy between touch and sight, since the retina is insensible to contact, and as well as the optic nerve, conveys, not a tactile, but a luminous impression to the brain. As for the other senses, if air in vibration comes in contact with the tympanum of the deaf man he perceives no sound, though he is sensible of contact from foreign bodies on the tympanum; if odoriferous or savoury bodies come in contact with the pituitary membrane or with the tongue of a man who has lost the sense of smell or taste, he perceives neither odours nor flavours, although he is perfectly aware of the presence of a foreign body in the nose or mouth.

The touch therefore cannot replace the other senses, though it sometimes corrects their impressions, but it needs to be constantly controlled and completed in the sensations which it produces in us. If it enables us to learn form, it is the eye which tells us of colour, and often perfects or corrects our notions of distance, extent, and even of form; as for instance, we distinguish less easily with the touch than with the eye a sphere from an ellipsoid which is nearly spherical. And besides it is when the touch has been exercised under the control of the sight that it furnishes us with the most exact ideas, for its results are then confirmed by those which we possess already in regard to time, motion, space, and the normal position of bodies, &c. Yet even in these conditions the sense of feeling may be the source of error. Müller says, and rightly too, that by touch we feel not

the object which touches us, but that part of the tegument where the contact takes place and the impression which it receives. The idea of external objects given by touch then is, when completely analyzed, the possibility of distinguishing the different parts of the body as occupying a different place in space. The result is, that if the parts of our bodies are momentarily in an abnormal condition, we receive, notwithstanding, the sensation in the relative order that the regions from which these sensations emanate preserve in a normal condition. If, for example, we cause a ball to revolve between two fingers of the same hand, we have the sensation of a single body touching these two fingers; but if we cross the fingers and place the ball between



Fig. 43.

their extremities, the sensation is that of two balls, each one rolling in contact with one of the fingers.

The sensations of touch are somewhat persistent, especially when the tactile impression is joined to that of general sensibility. Thus when we have carried a burden on the shoulder, or when any part of the body has been subjected to great and prolonged pressure, we still perceive the sensation sometime after the weight is removed and the pressure has ceased, but in such cases the tissues subjacent to the skin take part in the sensation as well as the skin itself.

The organ of touch may also be the seat of impressions which are subjective, or which arise from internal causes, physical or moral. The sight of a striking spectacle or the emotion caused by a narrative produces in some persons a

marked sensation of cold; the idea of shivering causes an impression which resembles it, and the fear of tickling is sufficient to produce its effects.

Feeling is modified by various influences; cold, or sanguineous congestion resulting from violent exercise, diminishes or suppresses for a time the sensibility of the skin; certain occupations, by thickening the epidermis, destroy the delicacy of the touch; and lastly, age diminishes the cutaneous perspiration, the epidermis dries up, and the skin no longer has the suppleness and elasticity which renders the touch so delicate in youth.

Tactile sensibility is often intensified by disease, and sometimes modified, suspended, or destroyed. We see this in trances which supervene after, or are provoked under, the influence of certain nervous affections. Charlatanism, even in our day, avails itself of this phenomenon, which we confine ourselves to simply mentioning here.

CHAPTER XVI.

Voice and speech.—Organ of voice; larynx, cavity of the larynx, glottis, vocal cords; the larynx at different ages and in different sexes.—Physiology of the larynx; mechanism of the voice; opinions as to the formation of the voice.—Galen, Fabricius Acquapendente, Dodart, Ferrein, Biot, Müller, Savart, Masson, and Longet.—Theories founded on laryngoscopic observations.—Formation of sounds in whistling.—Voice; speaking voice, mechanism of articulate sounds, vowels, consonants, timbre of the vowels; the tongue as an organ of pronunciation.—Singing; chest voice, falsetto voice, mixed voice; different theories on the formation of the falsetto: Müller, M. Segond, M. Longet, M. Fournié, M. Bataille, M. Mandl.—Timbres of the voice: high pitch, grave pitch.—Compass of voices: bass, baritone, tenor, contralto, mezzo-soprano, soprano.—Ventriloquy.

The larynx.—The organ of the voice is a sort of a cartilaginous tube composed of movable pieces articulated together, perfectly symmetrical, wider and triangular at its upper portion, which opens into the pharynx, cylindrical at its lower portion, where it is continuous with the trachea. It is placed in the anterior and middle portion of the neck and below the hyoid bone, to which it is united by muscles and ligaments, and in consequence it follows the movements of the hyoid bone and the tongue, rising and falling with them. Its movements are connected with deglutition, the acuteness and gravity of sounds emitted, and with respiration according as it is diaphragmatic or clavicular (see *Respiration*, p. 97).

Five cartilages form the skeleton of the larynx: they are

1. The *cricoid* cartilage (*cricos*, a ring); it is situated at the base of the organ, and is attached to the first ring of the trachea.

2. The *thyroid* cartilage (*thyreos*, a buckler), which is composed of two quadrilateral plates, joined together in front

and on the median line. This cartilage protects, as its name indicates, the organ of the voice. In front a ligament attaches its lower border to the cricoid cartilage, with which it is articulated behind; its anterior surface presents at the

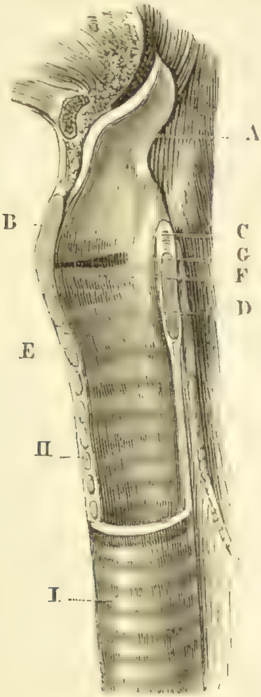


Fig. 44.—Section of larynx in the median line.

A. *Epiglottis, in front of which the hyoid bone and base of the tongue are seen.*
B. *Thyroid cartilage.*
C. *Arytenoid cartilage.*
D. *Posterior portion of cricoid cartilage.*
E. *Anterior portion of cricoid cartilage.*
F. *Vocal cord of right side.*
G. *Ventricle of the larynx.*
H. *Rings of the trachea.*
I. *Trachea.*

top an angular sloping protuberance, which is more marked in man than in woman. It forms the projection on the front of the neck which is called "Adam's apple." The upper border is united to the hyoid bone by a membrane and ligaments.

3. The two *arytenoid* cartilages (*arutaina*, a funnel); they

form the posterior and superior wall of the larynx, and come together behind in the shape of the lip of a ewer; they articulate with the cricoid cartilage, and are united to the thyroid by muscles and ligaments.

4. The *epiglottis* (*epi*, added to, *glotta*, the tongue) is a sort of cartilaginous valve, very elastic and mobile, situated a little below the base of the tongue, and attached to the superior border of the thyroid cartilage. Its function is to cover exactly the superior opening of the larynx during deglutition, so as to prevent the introduction of the food into the air-passages. When the tongue is brought well forward, and the base depressed, in some individuals the summit of the epiglottis is visible.

Numerous muscles attach the larynx to the sternum, to the hyoid bone, and by this last to the shoulder-blade, to the tongue, and to the lower jaw; these muscles are called *extrinsic*, and move the larynx as one piece. Others, called *intrinsic* muscles of the larynx, combine to form its walls, and to modify its diameter by acting on the cartilages, and assist in the functions of the glottis. Lastly, the arytenoid cartilages are united by ligaments to the epiglottis, or to the thyroid cartilage; these last, the *thyro-arytenoid ligaments* form, with the muscles of the same name and with the mucous membrane, the *vocal cords*, of which we proceed to speak.

The cavity of the larynx, or its internal surface, does not correspond in form and dimensions with the external surface; it is cylindrical at the bottom, triangular at the top: the dimensions of the lower part are invariable, while those of the upper portion, on the contrary, are variable in form, from the mobility of the epiglottis, of the arytenoid cartilages, &c. About the middle of its height the laryngeal cavity presents on each side a fold formed by the thyro-arytenoid muscles and lower ligaments of the same name, and the mucous membrane; these resemble two ribbons of a white colour tinged with rose, running horizontally from front to back, attached by their external border and their extremities to the wall of the larynx, free on the surface and internal border, leaving an opening between them which is linear, elliptic, or triangular, according to the moment when it is observed, and

whether we see the whole or only the two anterior thirds. This opening permits the passage of the air into and out of the chest, it is called the *glottis*, the folds which circumscribe it have been called the *vocal cords*. About one-third of an inch higher up there are two other similar but less prominent folds, they are formed by the superior thyro-arytenoid ligaments, and are designated by this name, or by that of the *superior vocal cords* (see fig. 44, p. 229). The space between them has been called the superior glottis, it is larger than the glottis proper, and does not resemble it in form when examined by the aid of the laryngoscope. Before this instrument was invented the larynx was described by anatomists as they saw it in the dissecting-room, hence the name of superior glottis, and the likening of this orifice to that of the glottis.

Between the vocal cords proper and the superior thyro-arytenoid ligaments there is on each side a depression; these are the *ventricles of the larynx;* and lastly, a little above these ligaments is the *superior opening of the larynx*, surmounted in front by the epiglottis, which is lowered upon, and covers it completely during deglutition. The space comprised between the glottis and the superior opening of the larynx is called the *vestibule* of the glottis.

Formerly authors were divided in opinion in regard to the larynx; some gave the name of glottis to all the region between the level of the inferior and that of the superior vocal cords, others applied it to the superior glottis, and others again to the inferior glottis only. This last opinion, which has been commonly received since the investigations of Bichat and Boyer, has been confirmed by the laryngoscope, which demonstrates the existence of a single glottis, and a single pair of vocal cords.

The internal walls of the larynx are lined with a fibrous membrane, constituted in part by yellow elastic tissue. This membrane, which forms the thyro-arytenoid and aryteno-epiglottic ligaments, is covered throughout its whole extent by a mucous membrane, which on the free border of the vocal cords is very thin and transparent, slightly adherent, and covered with an epithelium different from that found on the rest of its surface.

The larynx is but slightly developed in early infancy, and does not differ in its dimensions in the two sexes; and the characteristics of the voice are the same also. From the third to the twelfth year this organ remains nearly stationary; but about the fourteenth year it almost doubles in size in the boy, and the voice takes a masculine character. This evolution is rapid, and is nearly accomplished in the course of a year, though the larynx is not perfectly developed till the twenty-fifth year. In girls it augments about a third in size. The larynx, therefore, of an adult woman is smaller than that of man, its angles are less prominent, and the glottis is smaller. These differences are related to the characteristic pitch, compass, and power, which distinguish the voice of man from that of woman.

In diaphragmatic respiration the larynx is immovable; but when the expansion of the chest extends to the upper ribs, the sternum, and the clavicle, two of the extrinsic muscles of the larynx assisting in the elevation of the sternum, cause by their contraction the descent of the larynx, to which they are attached by their upper extremities. (See *Respiration*, p. 97.)

Physiology of the larynx, mechanism of the voice.—Like most physiological questions, that of the emission of the voice is differently explained by writers on that subject. In order to explain its functions, the larynx has been compared to different musical instruments. Gerdy thought "that we should do better to endeavour to show that this instrument in man has no resemblance to any one formed by art." This, doubtless, is true; the human larynx is as inimitable in its perfection as it is admirable in the results it produces; but, in comparing the most ingenious machines of this character that man has ever constructed, with the larynx, we do precisely what Gerdy recommends, for this is the surest means of establishing its evident superiority. The analogy is besides incontestable, in spite of the distance which separates an inert mechanical production from a living organic apparatus, and it is only by studying the formation of sounds in instruments that we can, if not explain, at least seek to comprehend their formation in the larynx.

The vocal apparatus of man is composed of the lungs, acting as a bellows; the trachea, which conducts the air from the lungs to the larynx, where the sound is formed; and of the pharynx, the buccal, and nasal cavities, which increase the sounds and modify their character.

The air driven through the glottis by the lungs causes a vibration of the vocal cords, and sound is produced; it is increased by passing through the upper part of the larynx, the mouth, and nasal fossæ; it acquires more or less volume, and its character varies according as these cavities are more or less open and free; but it does not change its nature as regards the tone. If, for example, the glottis emits a C, it may be heard as a muffled, a natural, or a nasal sound, according to the condition in which the cavities are through which it passes; but the tone does not change, it is always a C.

Savants have held different opinions on the formation of sounds in the larynx, and upon the functions of the constituent parts of the vocal organs. It being impossible to consider all these opinions, or the many experiments which have been made, the physical laws upon which they were founded, or which were opposed to them, we shall confine ourselves to a summary explanation of a few of them.

We may be permitted, however, first to quote from the *Magasin Pittoresque* an anecdote which very well illustrates this point of our subject:—

In 1798 Cuvier, in reading an essay on the voices of birds before the Academy of Sciences, remarked that some physiologists considered the larynx as a stringed instrument, others as a wind-instrument. An academician spoke and denied this distinction, affirming that everybody knew that the larynx was a wind-instrument. "You are in error," immediately exclaimed another member, "it is a stringed instrument."

These two theories have long divided philosophers.

Galen looked upon the glottis as a reed; Fabricius Acquapendente gave a remarkable description of the larynx in the sixteenth century; he recognized the glottis as the essential organ of the voice, and compared its action to that of an

organ-pipe; the air in breaking against it produced the sound, the glottis being less open for acute than for grave sounds.

Dodart at the end of the seventeenth century, after hesitating between the vibration of the air or the vibration of the vocal cords as the origin of sound, compares the glottis to the mouth-piece of a hautboy. This great physiologist, in giving successive explanations, differing as widely as possible from each other, of the phenomena of the voice, has advanced or hinted at most of the theories which have been projected since his time.

In 1741 Ferrein compared the vocal cords to the strings of a violin, the air acting as the bow.

Biot could see nothing in the glottis which resembled a vibrating cord. "The simplest principles of acoustics," said this illustrious physicist, "are sufficient to make us reject this strange opinion." Müller advocated the theory of Ferrein against that of Biot, and yet he admits with him and with Magendie, Cagniard de la Tour, G. Weber, and other learned men, that the glottis is a reed with two membranous lips vibrating under the action of the air, and producing the sound by their vibrations.

Savart compared the human glottis to a bird-catcher's whistle surmounted by a supply-pipe, the cavities of the whistle being represented by the ventricles of the larynx, the openings by the interval between the vocal cords. The air vibrated, he thought, in traversing the inferior glottis, and divided into two columns against the superior vocal cords, which act as the stop in an organ-pipe, one of these columns of air in vibrating causes the resonance of the air in the ventricles, the other causes the vibration of the air in the vocal tube. In this last hypothesis it is not the vibration of the vocal cords, but that of the air which produces the sound.

The theory of Savart on this latter point has been admitted by Longet and Masson. They believe the sound is produced at the orifice of the inferior glottis the same as at the mouth-piece of wind-instruments, by the periodically variable passage of the air, which becomes the seat of a vibratory movement. The inferior vocal cords and the ventricles are

necessary for voice; the superior vocal cords should be considered simply as a means of perfection in regard to the variation and modulation of sounds.

Haller thought the epiglottis had no influence on voice, but that it permitted the swelling of the sounds into grave or acute without changing the tone, as did also Magendie and Biot. Longet thinks that it assists in the expulsion of the air by the nasal fossæ in the production of very acute sounds, and that it may contribute to the timbre of the voice.

The part of the pharyngeal, buccal, and nasal cavities in the production and modification of sound is differently stated by different authors. Savart thought that they regulated the height of vocal sounds; they have been considered as supplementary apparatus, and that it is to their peculiar resonance that the quality of the voice is due.

The invention of the laryngoscope, by enabling us to see the interior of the larynx, has given us exact notions of its function. It enables us to verify the changes of form, the appearance of the glottis at different ages, and during the emission of the voice. This method of studying the larynx has resulted in late years in works of the greatest interest.

M. Fournié considers the larynx as a membranous reed-instrument, and the mechanism of the voice, according to this learned observer, is as follows:—The vocal cords produce the sound by their vibration, but do not vibrate in their totality. Fixed in front and at the back, at the level of their free border, they may be separated by the air, but not caused to vibrate in their entire thickness, while the mucous membrane which covers their free border, and which adheres only very slightly, detaches itself under the influence of the passing air, and thus forms the free vibrating portion of the reed. On this part only of the larynx the epithelium of the mucous membrane is of the same nature as that of the membranes in the other parts of the organism which are subjected to constant friction, as those of the articulations for example, and this gives it the power of resisting the friction of the air and of the vibrations which it causes. In the emission of the voice the vocal cords are stretched lengthwise and breadthwise. By producing mechanically this double tension

of the vocal cords in the larynx after death, M. Fournié obtained all the notes comprised between two octaves.

The ventricles of the larynx are contracted and almost effaced during the emission of the voice; their function seems to be to moisten the vocal cords with a mucous fluid, and to aid in their movements, as well as those of the walls of the vestibule and glottis.

The superior thyro-arytenoid ligaments adapt the tube formed by the vestibule of the glottis to the sounds emitted by the vocal cords. During the emission of sound their borders are never on the same line as the opening of the glottis; sometimes they approach the vocal cords, sometimes they almost disappear, or, on the contrary, enlarge into the vestibule of the glottis so as almost to fill it. By experiments on the dead subject, M. Fournié has proved that if these ligaments are drawn apart during the emission of a note by the larynx, the sound is lower by one tone; if only one is drawn aside it falls a semitone. The same result is produced in all the notes comprised in an octave.

The epiglottis descends and nearly closes the superior opening of the larynx in grave sounds, and rises more and more as the sound becomes more acute. In the grave notes the soft palate permits the sounds to pass through the mouth and the nasal fossæ, and in proportion as the voice is elevated it rises toward the posterior orifice of the nasal fossæ, so as to prevent the echoing of the sound in these cavities.

The nasal fossæ give exit to the air when the disposition of the vocal tube is such, in the formation of certain letters, as more or less to hinder its passage through the mouth. The isthmus of the throat and the mouth have no influence on the note, but they perfect and modify its character. The trachea and bronchia, as well as the vocal tube, resound like a harmonic table, of which each part corresponds to one of the notes of the voice; and lastly, the intensity of the sound is in direct proportion to the force of the impulsion of the air, to the extent of the vocal cords put in vibration, and to their tension.

Formation of sounds in whistling.—The study of the for-

mation of sounds in the glottis includes that faculty which man possesses of producing the sounds of whistling. This is certainly a much less important and less elevated function; but it is nevertheless very interesting to the physiologist, as it evidently nearly resembles that of the voice in its mechanism.

In order to produce the sound of whistling, the lips form a real glottis, which Dodart has named the *labial glottis.* The opening between the lips varies in form; in the grave tones it is nearly round in shape, and at its maximum in diameter; in the acute sounds it becomes elliptic, and is reduced to a narrow slit; the tongue regulates the intonation, by approaching more or less to the lower front teeth, touching them in the acute sounds, and withdrawing itself in the grave sounds. The space which separates the lips from the teeth varies also, in the same relative degree, for the same reason. The tongue sharpens the notes as in flute-playing; the grave sounds may be produced in drawing in the air, as in breathing; in short, the sound is acute or intense in proportion to the impulsion of the air by the lungs.

If a disk of cork be placed between the lips, about one-fifth of an inch in thickness, with a hole about one line in diameter in the centre, the sound of whistling can be produced through this aperture, and modulated the same as with the lips. Cagniard de la Tour, to whom we are indebted for this experiment, concludes from it that the sound does not proceed from the vibrations of the lips; but has its origin in those of the air, excited by an intermittent friction against their walls. Longet and Masson compare the apparatus for whistling in man to the whistle of a bird-catcher, and they find a close analogy between the labial and the laryngeal glottis.

Fournié rejects this theory, and supposes the sound of whistling to be produced by mechanism analogous to that of an organ pipe, the air breaking against the stop, which is represented by the upper incisors. Whichever doctrine we may accept, it is certain that the lips, or the perforated disk which replaces them, play an important part in the production and modification of sound in ordinary whistling, for

when these sounds are made without the aid of the lips, by a peculiar disposition of the tongue, it is only a single sound. It is the same in whistling through the teeth with the lips drawn apart, or when the tongue being doubled, and the fingers placed in the mouth, we produce an intensely acute sound, but which cannot be modulated.

In the apparatus for whistling, as in that of the voice, the functional disposition, and its modifications in relation to the sounds emitted, takes place by movements under the control of the will, although they are, so to speak, instinctive. The changes in the dimensions of the orifices and of the buccal tube, in the tension of the walls of the mouth, the impulsion of the air, &c., are all effected instantaneously, and in such a manner as to produce all the notes. No instrument of music equals the perfection of this apparatus.

Voice.—Voice is a sound produced in the throat by the passage of the air through the glottis, as it is expelled from the lungs. It is grave and strong in man, soft and higher in woman; it varies according to age, and is developed simultaneously with the larynx, as has already been stated. It is alike in both sexes in infancy, but is modified in youth; then the voice is said to "change." In the young woman it descends a note or two, and becomes stronger. In the young man the change is much more strongly marked. At the fourteenth or fifteenth year the voice loses its regularity, becomes harsh and unequal, the high notes cannot be sounded, while the grave ones make their appearance, and the masculine character of the voice is established. A year is generally sufficient for this change to be complete, and the voice of the child gives place to that of the man. Exercise of the voice in singing should be very moderate, if not entirely suspended, while this change is going on.

Speaking voice.—Voice is divided into singing and speaking voice. One differs from the other almost as much as noises do from musical sounds. In speaking, the sounds are too short to be easily appreciable, and are not separated by fixed and regular intervals, like those of singing; they are linked together generally by insensible transitions; they are not united by the fixed relations of the gamut, and can only be noted with

difficulty. That it is the short duration of speaking sounds which distinguishes them from those of singing, is proved by this, that if we prolong the intonation of a syllable, or utter it like a note, the musical sound becomes evident. And if we pronounce all the syllables of a phrase in the same tone, the speaking voice closely resembles psalm-singing. Every one must have noticed this in hearing school-boys recite or read in a monotone, and the analogy is complete when the last two or three syllables are pronounced in a different tone. Spoken voice is moreover always a chant more or less marked, according to the individual and the sentiment which the words express. The accentuation peculiar to certain languages also gives the speech the character of a chant: to a French ear an Italian preacher seems always to sing. It is a chant also which is caused by all those inflections of the voice, which express our sentiments and our passions, and which vary with every thought. They extend from the feeble murmur, which the ear scarcely perceives, to the piercing cry of pain. Affectionate, sympathetic, imperious, or hostile, they sometimes charm, sometimes irritate, and always move us. It is related of Grétry, that he amused himself by noting as exactly as possible the "Bonjour, monsieur!" (Good day, sir!) of the persons who visited him; and these words expressed by their intonation, in fact, the most opposite sentiments, in spite of the constant identity of the literal sense. Baron, the comedian, moved his audience to tears by his recitation of the stanzas of the song, "*Si le roi m'avait donné Paris sa grand'ville*"—If the king had given me Paris his great city.

Mechanism of articulate sounds.—Writers are not in accord in explaining the pronunciation of letters, that is, the mechanism of articulate sounds; but, whether grammarians or physiologists, they all class the letters according to the parts of the vocal apparatus which co-operate in their pronunciation, as labials, dentals, gutterals, &c. The division of the signs of the alphabet into vowels and consonants expresses the universal idea that a vowel is a voice, a sound perfect in itself, while a consonant cannot be sounded without the help of a vowel associated with it. The consonants, indeed, do

not make even a noise, a murmur; but they give a peculiar character to a vowel sound. We find something in the playing of an instrument analogous to this function of a consonant. If we pinch the string of a violin, or strike a bell with a hammer, a sound is produced which we imitate with the voice by prefixing a *t* or *d*, as *dinn*, *tinn;* if the string or the bell be made to vibrate with the bow, the sound as reproduced by the vocal organ is preceded by the letters *cr*, whence the imitative French word *crin-crin*. The hammer and bow are the consonants, the note of the bell or the violin is the vowel.

Helmholtz has demonstrated, as we have already observed in speaking of hearing, that the timbre of sounds is determined by the harmonics. He was able by means of ingenious instruments to decompose the sounds which only produce a single sensation, and which seem to us simple, though they are really composed of elementary sounds more or less numerous. This analysis enabled him to discover the laws under which the quality of the sounds is constituted which are emitted by the glottis, and resound in the vocal tube under the form of vowels. Among the elementary sounds composing the sound emitted by the glottis, the vocal tube exalts a particular one by preference, and it is this one which gives to the vowel its characteristic timbre. The vocal tube disposes itself in a special form for each vowel. It lengthens or shortens, dilates or contracts; it places itself, in a word, in conditions essential to the strengthening of the sound which determines the timbre. Each vowel is therefore characterized by a note, but each one has a particular affinity for certain notes; it is sometimes difficult, or even impossible, to give such a note on another vowel than that with which it corresponds, and thus singers are sometimes forced to substitute one vowel for another.

In seeking in the different qualities of the voice, and especially in the vowels, for the seat of the resonance of sounds in the buccal tube, and the parts which co-operate in this resonance, Fournié has made a classification of the letters, which he claims to have rendered more exact and more anatomical than any of his predecessors. The tongue,

the teeth, the lips, and the throat, are the parts by which most of the letters are formed. To these Fournié adds the palate for some of them, and the glottis for the *h*, which, until recently, was classed among the gutturals. It is unnecessary to remark that in the study of the vowels in their relation to the mechanism of articulate sounds, the laryngoscope has given invaluable aid.

The manner of forming the vowels differs from that of the consonants in this respect: the parts which co-operate in the formation of the vowels must be fixed during the utterance of the vowel, while the articulation of the consonants is effected by a movement of the parts essential to their formation. Thus "*p*," is enunciated by suddenly opening the lips which have been previously closed; and in the same way the other consonants are pronounced by some movement; and this movement is in accordance with the disposition of the parts necessary to the utterance of the vowel which precedes or follows the consonant.

Of all the parts which serve for the articulation of sounds, the tongue is the one which plays the principal part, and therefore it gives its name to the whole group of modulations of the voice which constitute language, or as we sometimes say, *a tongue*. And yet observation teaches us that the volume of the tongue may be greatly diminished, or may even exist only in a rudimentary state, without its being impossible to speak.

De Jussieu relates that he saw a girl fifteen years old, in Lisbon, who was *born without a tongue*, and yet she spoke so distinctly as not to excite the slightest suspicion of the absence of that organ.

The *Transactions of the Royal Society of London* (1742) contain a report of the commission which was appointed to investigate a case of a similar nature. It was a woman who had not the slightest vestige of a tongue, but who could, notwithstanding, drink, eat, and speak as well and as distinctly as any one, and even articulate the words in singing. Other instances have been known where individuals, after losing a portion of the tongue by accident or disease, have again been able to speak after a longer or shorter time.

Singing.—We generally recognize two series of sounds in the voice in singing, one comprising the grave and semi-acute notes, and the other the high notes; this is called the *register* of the voice, one is the *chest register* or voice, and the other the *head register* or voice, or *falsetto.* Some writers admit a third series or *mixed voice*, which resembles a diminutive chest-voice, in quality and in the disposition of the glottis when it is produced.

We have indicated already the principal physiological theories on the formation of the voice in general: there is no less diversity in opinion in regard to the falsetto. According to Müller, it results from the vibrations of the edge only of the vocal cords; other authors incline to the notion that the glottis no longer vibrates like a reed, but like the mouthpiece of a flute. M. Segond makes the falsetto voice to come from the superior glottis exclusively, that is to say, from the vibration of the superior thyro-arytenoid ligaments. This opinion has been refuted by the experiments of M. Longet. And lastly, Weber and Longet attribute the origin of the falsetto notes to the harmonics of the vocal cords.

The laryngoscope enables us to study the glottis during the emission of the chest-notes, and even of the falsetto notes, but observers are not agreed upon the phenomena which they have observed.

According to Fournié, the chest, the falsetto, and the mixed

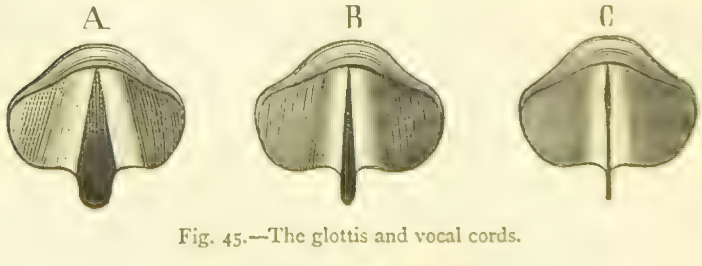


Fig. 45.—The glottis and vocal cords.

A, B. *Glottis in the chest-voice.*
C. *Glottis in the falsetto voice.*

voice, are all produced by the vibration of the mucous fold which covers the free border of the vocal cords.

In the chest-voice the larynx descends very low and the vocal cords are horizontal and stretched simultaneously in length and thickness; the superior thyro-arytenoid ligaments project, and partly hide the external border of the vocal cords; the epiglottis is slightly inclined over the opening of the larynx; the transverse diameter of the glottis is very small and linear, and the edges of the vocal cords are very thick and rigid. The larynx rises in proportion as the tone grows higher, the epiglottis straightens again little by little; the plane of the vocal cords inclines; the orifice of the glottis shuts progressively from behind forward, and consequently the vibrating portions diminish in length, while at the same time the tension increases.

In the falsetto, the larynx is carried upward and backward against the spinal column, the soft palate rises, and its posterior pillars approach each other, the ventricles of the larynx are obliterated, the vocal cords are wholly visible, and their borders are in contact for half their length at least. The glottis is therefore closed behind, and its orifice, very much smaller than it was during the utterance of the chest-notes, diminishes progressively as the notes grow higher.

In the mixed voice the glottis is open throughout its whole length, and its transverse diameter is greater than for the other registers.

According to M. Battaille, in the chest-voice the cords vibrate throughout their extent, the opening of the glottis is rectilinear, there is less tension in the walls of the vestibule and glottis, and on the contrary more in the vocal cords, than in the falsetto voice. In the falsetto voice, the arytenoid cartilages embrace each other by a sort of reversion in the two upper thirds of their internal surface, the glottis then being ellipsoid in form and more open behind than in the chest-voice.

This form of the glottis, which is attributed by the eminent artist to the falsetto voice, is precisely the same that M. Fournié has seen in the mixed voice, which requires less effort.

M. Battaille is the only author who notes the joining of the arytenoid cartilages by their internal surface: others

admit that they approach each other at their borders only, so as to close the hollow which separates them behind, and to cause the vocal cords simultaneously to face each other through part of their length.

M. Mandl has kindly communicated to us the result of his numerous observations on this subject; according to his opinion, in producing the chest-voice the arytenoid cartilages are separated behind; in the falsetto, *in a normal condition*, they approach and join each other on their posterior border, which causes the vocal cords to face each other—as M. Fournié also says—behind, while they remain separated in front by the slit of the glottis, which has become elliptic and much shorter; in certain persons, however, we observe something analogous to the joining of the arytenoid cartilages which M. Battaille describes, and which belongs to the *normal condition* of the larynx. In fact, when one of these cartilages is anchylosed at its point of union with the cricoid, and does not move to meet its congener, the latter supplies the defect and covers it by a sort of overlapping.

Timbres (the distinctive quality of voices).—Besides that quality which is peculiar to each individual, the voice may have several others, some of which, as purity, are due to the perfection of the entire vocal apparatus, and others, as the hoarse nasal or guttural quality, arise either from the unskilfulness of the singer or from some change in the organ. There are two forms, however, remarkable because they may be produced at the will of the artist, these are the *muffled* voice and the *clear* voice. Their names indicate their nature. In the muffled, the sound is rounder, more velvety, and resembles less the sound of a reed; the pronunciation of the letters is less distinct and sharp, and the noisy vowels, like the *a* and *e*, incline to the timbre of *o* and *u*. In the clear voice the sound is piercing, somewhat noisy, and less agreeable to the ear. This high key is more common among the northern nations of Europe, while the graver one is ordinarily adopted by the singers of the south.

It is generally admitted that the muffled voice is caused principally by the immobility of the larynx when as low as possible, and in fact the larynx is usually in that position in

singing in this tone: though M. Segond has occasionally seen the larynx as *high* as possible when this voice was produced. This voice seems to depend on the narrowing of the buccal orifice and the isthmus of the throat, coincident with as great a dilatation of the mouth as possible, a disposition which muffles and veils the resonance of the sound in the cavities of the pharynx and vocal tube. If in singing the letter *a*, with the mouth wide open, the lips be made slowly to approach each other, and pressing them together without extending them, the sound passes from the clear to the muffled tone, and the vowel *a* sounds like *o*. This movement of the lips was very apparent in Mademoiselle Giulia Grisi in certain high notes, but even her admirable voice was insufficient to make us pardon her for thus marring features worthy the pencil of Raphael.

Diapason of voices.—Male voices are divided into *bass*, *baritone*, or singing bass, and *tenor*. The voices of women are the *contralto*, which corresponds to the baritone, *mezzo-soprano*, and *soprano*. The extreme limits of these voices are, for the base the G below the CC; for the soprano, the F *in alt.* or the F of the last octave but one of the piano. Mozart heard a singer at Parma who gave the C above. Ordinary voices do not go beyond two octaves, but celebrated artists have compassed three and even three and a half octaves.

Fortunately the prodigious compass of such a voice is not necessary to entrance a real lover of music. The artist is always sure to triumph when to correct intonation he joins sympathetic quality, and, what is rare, that good taste which will not permit him to sacrifice the expression and the character of the music to a desire to shine.

Instrumental music awakens in us the most profound emotions; we are transported by Baillot's violin or the orchestra of the Conservatory, but no instrument can equal the impression produced by a beautiful voice; no instrument can pretend to those sounds, soft or sharp, passionate or purely peaceful; none has that variety in quality, those accents which fascinate us and plunge us into ecstasy. Instruments and their voices are prodigies of art, but the human

voice is living sound, as the glance of the human eye is animated light.

Ventriloquy.—Those who created the word ventriloquy evidently believed in a voice produced by some other organ than the larynx. But in these days every one knows that what is called ventriloquy consists in concealing the origin and nature of the voice. The ventriloquist speaks with his lips nearly closed, and he so modifies the sound of his voice as to make it seem like that of a child, or a woman; he makes us believe that it comes from a chimney or a cavern, from the far distance, from the sky, or from the bowels of the earth. In the last century the French Academy of Sciences appointed a commission to study the phenomena of ventriloquy in a man exceedingly skilful in the art, but acting in good faith and making no mystery of his power. It is to the uncertainty as to the direction of the sounds, and to the errors into which we are easily led by the organ of hearing, more than to anything else, that the ventriloquist owes his success. They may deceive ignorant and credulous people, but they are generally content to amuse their auditory, and in that they succeed.

CHAPTER XVII.

Physiognomy; study of it in works of art.—Movements of expression, their seat.—Colouring of the skin; paleness, redness.—Expression of the muscles; effort, muscles of the face.—Physiognomy of the senses.—Expression of the eyes, vision, easy or difficult, blindness.—Expression in the act of hearing, easy or difficult, hearing of an orator, musical hearing.—Expressions of smell and taste. Expressions relating to the touch.

Physiognomy is generally considered as the expression of the features of the face, but it is not so limited in its elements. Attitude, repose or action, fulness or slenderness of form, proportion, bold or graceful relief, and lastly, health or disease have, in the entire contour of the body, a signification which completes that of the face. Physiognomy, therefore, is the expression which form and motion give to the body.

In the Caryatides of the temple of Erectheus, we admire the calmness and grandeur, the majesty of the draperies, the simple and grave lines of the figures which support without effort the marble that seems not to weigh upon them. In the Caryatides of Puget at Toulon, we see the display of power in the violently contracted muscles, in the arms which seek to relieve the head from the burden, under which the whole body stiffens, and is about to succumb!

Compare a Silenus to the Farnese Hercules. In the old friend of Bacchus, the form is heavy, obese, and flaccid; it is the abjectness of drunkenness; in the other, the powerful muscles, the firm proud attitude, the noble bearing, declare the tamer of monsters and of vices. The Diana Huntress, with her sure and rapid step, is the enemy of idleness and repose; her manner is severe, and human passion has never

throbbed in her virgin breast. The Venus Anadyomene, graceful, timid, uncertain in manner, shows much more of feeble humanity.

It is to this profound sense of physiognomy in the great artists that we owe the lively emotion which the sight of their master-pieces produces, and the ancients do not, in our judgment, merit the reproach cast upon them for the want of expression in their heads.

The Greeks, for whom statuary was especially a monumental art, gave to their faces the calm and dignity of gods, rather than human passions; therefore the action was quiet, the lines simple, and the expression of the head in harmony with that of the body; but when they turned to dramatic subjects, the few examples which remain enable us to judge that they were not less admirable in works of this nature.

They no doubt guarded against empty grimaces, and it was principally in action that they placed the expression: but can we not read disdainful anger on Apollo's lip? and is not pride stamped on the features of the Venus of Milo? does not watchfulness careless of danger look from the eyes of the Gladiator, and love, almost paternal, rest on the simple, spiritual head of the Faun and Child? Do we not feel a mother's pain in the Niobe, see the suffering and the prayer in the look of the Laocoon? The sculptors of the Renaissance imposed the same rule upon themselves before the works of antiquity were revealed to them. They were followed also by the painters, although for them these rules were less inflexible, and yielded more to details in an art more nearly allied to living nature.

The artist finds in anatomical physiology, and in physiognomy, useful hints and precise principles: but he rightly abstains from a rigorous and servile application of them, for though the physician may find it important to know the exact function of a certain muscle, the sculptor and the painter must confine himself to the true but not realistic expression caused by its contraction. To go beyond this, which is very easy, is to arrive at that repugnant reality which certain masters of the Spanish school have not hesitated to adopt.

Caught from nature by photography, physiological expression belongs to science, and is invaluable to it; but the artist, like the poet, remembers that his task is to suggest only, leaving that to be divined which could not be said or delineated without revolting the spectator.

The movements from which the physiognomy results are always harmonious, and it is to their unity and concordance that our impressions are due. The least negligence in this respect shocks us in a picture like a false note in an orchestra, while our admiration is unbounded for a work of art in which nothing is forgotten.

Lethière paints Brutus at the execution of his sons; the face and attitude of the consul express only merciless severity, the folds of the toga are faultless, but the contracted hands reveal the agony of the father under the inflexibility of the judge. David represents him to us at the moment when the bodies of his sons are brought to him. The expression of the head is fierce, the feet, the left hand, and the whole body are strongly contracted; the right hand alone is carelessly bent, and takes no part in this convulsive state.

Movements of expression.—Gratiolet, in his treatise on physiognomy, groups under this term all the modifications of form, of colour, &c., which manifest themselves on the surface of the body, under the influence of the most widely different causes. These movements are *direct*, *sympathetic*, or *symbolic*.

In looking at an object, the action of the eyes, and the animation which they give to the expression, are *direct* movements; but if we fix the attention, the body takes part in the action of the eyes, inclines forward, and seems to wish to move toward the object observed; these are *sympathetic* movements, and when thinking of extreme cold we shiver, this is a *symbolic* movement.

The limbs, the trunk, and the head, that is to say, the gestures and attitude, contribute greatly to complete the physiognomy, as has already been remarked; the cavities, on the contrary, take no part in it, the seat of expression is in the skin, the muscles, and the eyes.

Colour of the integuments.—The skin, particularly on the

face, takes the greatest variety of tints, from a violet red to a livid pallor, under the influence of physical or moral causes, which quicken or retard the circulation of the blood; but besides the colouring of the face, it is the movement of the muscles, and the expression of the eyes, which gives it a definite signification.

In a feeble man the motion of the heart is retarded, or sometimes hurried, as if to make up in the number of its beats for their want of energy; the blood is not sent to the surface in sufficient quantity, and the face is pale; but the languor of form and look denote the cause of the pallor.

Cold causes contraction of the tissues, the circulation is impeded on the surface of the body, the features seem pinched, the lips, nose, and cheeks take a livid leaden hue; chills sometimes shake the limbs and the lower jaw; on the face, as well as over the whole body, the integument is the seat of a painful constriction, but the eyes only express suffering. When an assassin reproached Bailly with being afraid, he replied, "No, my friend, I am cold."

Violent exercise, joy, confusion, fury, all quicken the action of the heart, and precipitate the movement of the blood through the teguments, which relax or yield to the impulsion of the fluid; but the open mouth, the dilated nostrils, the heaving chest, the strong and rapid respiration, express, as well as the features, an agitation purely physical, and we are not tempted to assign a moral cause for the flush which follows muscular effort. The serenity and expansion of the features, the smile, the brightness and happiness expressed in the eye when the face is flushed with joy, have nothing in common with the downcast eyes, the falling lip, the muscular weakness, and embarrassed manner of the man who reddens with confusion. We easily recognize also the haggard and threatening eyes, the knitted brow, the compressed lips, and the violently contracted or strongly agitated muscles of a man who is a prey to anger, and in whom the blood, at first impeded in its course, now in its reaction forcibly injects the integuments.

We see by these few examples that the colouring of the skin, varying under the influence of the most diverse causes,

is an important element in physiognomy, though its signification is doubtful, and must be completed by the expression of all the other features, or of the body.

Expression of the muscles.—The action of the muscles and the movements resulting from it, have, on the contrary, a special character, whether taken as a whole or individually, in certain muscles of the face. In making an effort, these movements embrace the whole muscular system, and the expression which results is more characteristic. When reproduced by the plastic arts, it strongly impresses the spectator, who feels a sort of sympathetic contraction, but which soon fatigues and irritates like all inconstant attitudes.

The muscles of the face by their single or combined contraction cause the most widely differing expressions, and correspond to all the sentiments, whether simple or complex. Thus, the muscle of the forehead raises the brow in attention, admiration, or astonishment; that of the eyebrow contracts it with pain; the great zygomatic raises the angle of the lips in laughing; the triangular muscle of the lips draws them downward in weeping; other muscles co-operate in expressing combativeness, fear, anger, irony, &c., in short, the slightest phase of feeling is reproduced in the features, by the slight or energetic contractions of the muscles, which carry with them the skin to which they are intimately united, wrinkling or distending it. An eminent physiologist, M. Duchenne of Boulogne, particularized the action of these muscles in expressive movements. But though some of them may play a distinct part in the mimicry of the face, others always join in the movements when the sentiment or sensation acquires a certain vivacity; thus the muscle of the eyebrow alone may express a certain degree of suffering, but when it becomes intense the eyelids close, the nostrils dilate, and other signs beside prove the simultaneous action of the different muscles. For the physiologist and the physician, rigorously exact facts of this sort have the greatest value; but they are of less consequence to the artist, who must represent not only the muscle but the whole of the parts, near or distant, to which its action extends. If it is necessary for him to understand anatomy and the function of the muscles

in order to reproduce exactly their projection during movements of the body and limbs, it is much more the study of the living model which guides him when endeavouring to render the expression of the features; and if he fails in this, it is less from ignorance of anatomy than from lack of sentiment or incapacity.

It is remarkable also how much opinion varies in regard to works of art. Each individual brings to their examination the predisposition of his studies; and if the naturalist may sometimes criticize justly, sometimes also in his judgments the artistic sentiment is replaced by the rigorous formulas and exact notions of science; he does not consider that the artist should avoid being as exact as a Chinese copy, and that a profound artistic sentiment should be completed in its expression by its counterpart in the spectator. And lastly, a savant may be a man of genius, and still lack all artistic sentiment. Gratiolet, that fine and noble mind, could see nothing in Raphael's "Creation" but a "deplorable work—a furious old man striving with feet and hands to separate two thick clouds." The man who criticized one of the most admirable master-pieces of art in these terms, was a scholar of the first order, a great physiologist, and has left a work on physiognomy itself marked by the most delicate perceptions and the most profound study.

Physiognomy of the senses.—The more the mind predominates over matter, and separates itself from it, the more elevated will be the expression of the physiognomy. Faith and prayer transport man into an order of ideas purely intellectual, and give to the features a character in which sense has no part. Resignation attaches itself to the terrestrial affections, and mingles with them an element of pain which, whether moral or physical, is always expressed by the marks of suffering. The recital of a dishonourable action adds a shade of disgust to indignation, and the moral impression seems to affect our organs as they are affected by material impressions.

This indirect and, as it were, figurative action of the senses on the physiognomy, mingles incessantly with movements of another order, and often expresses itself with as much energy

as the real sensations. When these latter are acute they govern the expression almost as completely as the most violent passions, and may, like them, impress upon the features the sign of an infirmity, a fault, or a vice.

Our senses, as has been already stated, are united by the constant relations of complementary or sympathetic functions, as the sight and the touch, the sight and the hearing, the taste and the smell frequently control or complete each other by their simultaneous action, and often all the senses are in action at once. This coincidence of the sensations reflected by the physiognomy is a source of varied and complex expressions, as much so as the nervous impressions transmitted to the brain can be, and to describe the physiognomy of any one sense it is necessary almost to draw all the features of each of the other senses.

The *eye* gives an expression of intelligence to the physiognomy, and reflects the thought more than any other organ of the senses. It is especially through the eye that the passions reveal themselves—that joy or sorrow, courage or fear, envy, love, or hate, frankness or duplicity, are expressed on the features; therefore, says one, if you would know a man's sentiments, read them in his eyes.

The movements of the globe of the eye, its fixity, and the contraction or dilatation of the pupil, infinitely vary the expression of the face, and give to the whole of the features a decided meaning; but to the mimic language of the globe the eyelids bring an important and often decisive addition.

When sight is good, attention is expressed without effort: the face is calm; the eyelids, moderately open, show the globe of the eye, which fixes itself on the object, follows it in space, and acts, in short, as do all the organs in a normal condition, without any consciousness; but if, on the contrary, it is necessary to distinguish an object which is perceived with difficulty, the eyelids approach each other, the eyes twinkle, and the immobility of the body, the suspended respiration, denote more marked attention; the brow contracts, and the features wear an expression of pain, which sometimes gives short-sighted persons a forbidding character.

The face of a blind man is rarely sad, but the immobility

of the features, which are so animated by vision, produces a painful contrast.

In *hearing* the attention is also more or less characteristic. If we wish to distinguish a distant noise, or perceive a sound, the head inclines and turns in such a manner as to present the external ear in the direction of the sound, at the same time the eyes are fixed and partially closed. The movement of the lips of his interlocutor is the usual means by which the deaf man supplies the want of hearing; the eyes and the entire head, from its position, have a peculiar and painful expression of attention. In looking at the portrait of La Condamine it was easily recognized as that of a deaf person. Even when hearing is perfect the eyes act sometimes as auxiliaries to it; in order to understand an orator perfectly, it seems necessary to see him—the gestures and the expression of the face seem to add to the clearness of the words. The lesson of a teacher cannot be well understood if any obstacle is interposed between him and the eyes of the listening pupil.

That species of intoxication which we term ecstasy is expressed on the features of a musical amateur on hearing a master-piece; all the powers of attention are concentrated on one organ; the features are slightly contracted by the smile or other expression in accordance with the character of the music; the eyes are half shut or closed, though sometimes they are fixed agonizingly on the singer in some difficult passage, or enthusiastically on some leader, like Habeneck, leading his orchestra with a passionate gesture.

If a piercing, harsh, or discordant sound strikes the ear, the eyes close, and at the same time the lips, the nose, and the whole face contract as if the other senses were combining to protect the hearing from the pain it endures, and against which its immovable organ cannot defend it. It is impatient suffering, and no longer the charm of a delicious sensation.

Under the influence of the *smell* and the *taste* the expression of the physiognomy is extremely varied, and reflects perfectly the delicacy or the force of the sensation, the degree of pleasure which accompanies it, or the horror and repugnance which it excites in us. Here, as in hearing,

sympathetic movements are combined with the direct movements produced in the affected organs. When taste is concerned, it is very rare that they are not confounded, for almost always the aroma is combined with the taste, and either perfects its excellence or renders it still more insupportable. But whether it expresses satisfaction or antipathy, the play of the physiognomy in sensations of this nature has nothing elevated in it, rather it unveils a certain abasement of the individual; hearing and sight are in immediate connection with the most precious faculties of the mind, while taste and smell appeal specially and directly to our material appetites. But we must not therefore judge too severely the elation of a gourmand seated at a well-spread table. The best compliment he can offer to his host is to show a worthy appreciation of an exquisite repast. We shall see the spirit of our guest, vivified by the sweet influence, shine from his eyes with a light which will easily enable us to pardon what little of sensuality there is in his mouth.

It is by the *sense of touch* that we acquire clear ideas of the form of bodies, of the distance, resistance, weight, temperature, &c. It confirms the testimony of our eyes, and joins its impressions to those of sight often in an effective manner, and always through the mind.

The touch produces expressive movements in us then, in connection with our tactile or visual sensations; and these movements are sometimes direct, as in effort, and sometimes sympathetic and an indication of the impressions produced on the skin. Lastly, touch is the origin of symbolical movements by which we express the thought of bringing an object near, or putting it away from us. To this sense are related the gestures which accompany our words. We affirm a fact by so placing the hand as if we would rest it firmly on a body; we deny by a gesture putting the false or erroneous proposition away from us; we express doubt by holding the hand suspended, as if hesitating whether to take or reject. When we part from dear friends, or greet them again after long absence, the hand extends towards them as if to retain, or to bring them sooner to us. If a recital or a proposition is revolting, we reject it energetically in gesture as in thought.

In a friendly adieu we wave our good wishes through space to him who is the object of them; but when it expresses enmity, by a brusque movement we sever every tie. The open hand is carried backward to express fear or horror, as well as to avoid contact; it goes forward to meet the hand of friendship; it is raised suppliantly in prayer toward Him from whom we hope for help; it caresses lovingly the downy cheek of the infant, and rests on its head invoking the blessing of Heaven; in a word, the touch, real or imaginary, is constantly adding a feature to the physiognomy.

THE END.

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